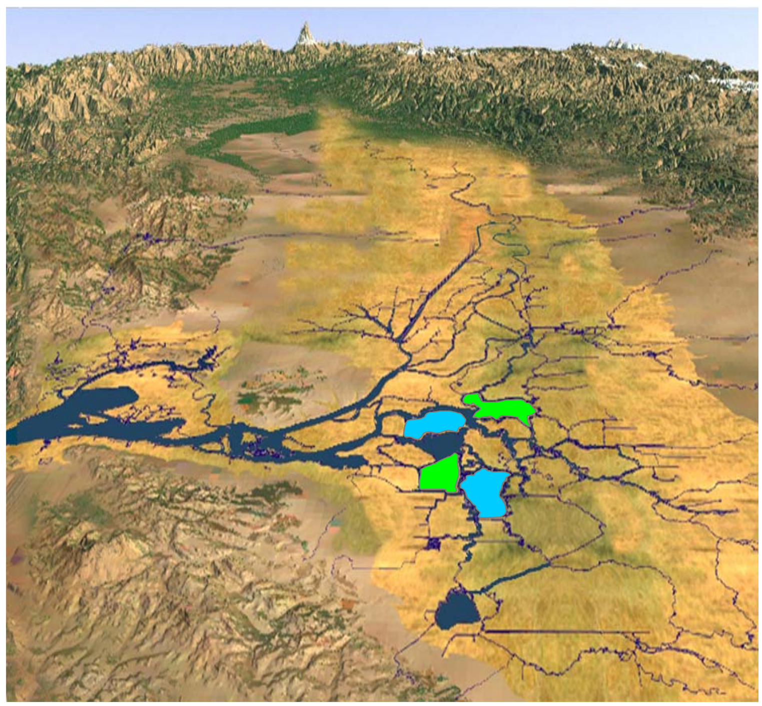
INTEGRATED STORAGE INVESTIGATIONS

DRAFT
SUMMARY REPORT
IN-DELTA STORAGE PROGRAM
STATE FEASIBILITY STUDY



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DEPARTMENT OF WATER RESOURCES
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Division of Planning and Local Assistance
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ORGANIZATION

FOREWORD

We acknowledge the technical assistance provided by the U.S. Bureau of Reclamation (Reclamation) in carrying out the role of federal lead agency for the CALFED Integrated Storage Investigations. Reclamation will continue to provide technical assistance through the review of the State Feasibility Study draft reports and DWR will work with Reclamation to incorporate comments and recommendations in the final reports.

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Table of Contents

Chapter 1: GENERAL 1

1.1 Introduction 1
1.2 Role of Storage in Delta Ecosystem and Water Supplies 3
1.3 Feasibility Study Management and Coordination 5
1.3.1 Institutional Setting 5
1.3.2 Public Outreach 5
1.4 Summary of Findings 7
1.5 Potential Future Actions 9

Chapter 2: PROJECT BACKGROUND 10

2.1 Link to CALFED Programmatic EIR/EIS Process 10
2.2 Study Progression from Planning to Feasibility Level 11
2.3 Project Description 12
2.3.1 Embankments 13
2.3.2 Integrated Facilities 13

Chapter 3: OPERATION STUDIES 16

3.1 General 16
3.2 Operational Criteria 17
3.2.1 Level of Development 17
3.2.2 Operational Criteria for No Action Base Alternative 17
3.2.2.1 Water Quality Control Plan D1641 Requirements 17
3.2.2.2 CVP/SWP Operations Under Coordinated Operations Agreement (COA) 18
3.2.2.3 Joint Points of Diversion 18
3.2.3 In-Delta Storage Project Operations 19
3.2.3.1 SWRCB Decision 1643 Requirements 19
3.2.3.2 CVPIA 20
3.2.3.3 Groundwater and Surface Water Conjunctive Use 21
3.3 Operations Modeling 21
3.3.1 CALSIM Model Development 21
3.3.2 Interactive CALSIM II Model Applications 21
3.4 Operations Scenarios 22
3.4.1 Study 1: No Action Base Operations 23
3.4.2 In-Delta Operations 23
3.4.2.1 Study 2: Water Supply Study 24
3.4.2.2 Study 3: Water Supply Study with EWA 24
3.4.2.3 Study 4: Water Supply Study with EWA and ERP 24
3.5 Impact Evaluation Studies 25

3.5.1 Study 4a: Initial Project Conditions with DOC Constraints Applied 25
3.5.2 Study 4b: DOC Dilution through Circulation 26
3.5.3 Study 4c: Fish and Aquatic Habitat Protections during Drought and Most restrictive 26
3.5.4 Study 4d: Climate Change Impact 27
3.5.5 Study 4e: Coordination with Los Vaqueros Expanded Reservoir 27
3.5.6 Study 4f: Impact of D1643 on In-Delta Storage Operations 28
3.6 Regional and System-wide Evaluations 31
3.6.1 Water Supplies Reliability 31
3.6.2 SWP and CVP System Operational Flexibility 32
3.6.3 Carryover Storage 33
3.6.4 Environmental Water Account 34
3.6.5 Ecosystem Restoration Program 34
3.6.6 Water Quality 35
3.6.6.1 Salinity 35
3.6.6.2 Organic Carbon Evaluations 36
3.6.7 Assessment of Fish and Aquatic Habitat Protections 39
3.6.8 Impact of Climate Change 40
3.6.9 Impact of D1643 Actions 40
3.7 Conclusions and Recommendations 41

Chapter 4: WATER QUALITY EVALUATION 43

4.1 General 43
4.2 Water Quality Requirements 43
4.2.1 General Requirements 43
4.2.2 Specific Requirements 44
4.3 Water Quality Field Investigations 44
4.3.1 Development of Conceptual Model 45
4.3.2 Materials and Methods 46
4.3.3 Use of OC Field Data in Modeling 51
4.4 Delta Simulation Model (DSM2) Modeling Studies 51
4.4.1 Simulated Constituents 52
4.4.2 DSM2 Physical Representation of the Project Islands 53
4.4.3 Delta Barrier Operations 53
4.4.4 Delta Water Quality 54
4.4.5 Project Island EC 55
4.4.6 Project Islands DOC 55
4.4.7 Seepage 56
4.4.8 Operation Strategies: Circulation 57
4.5 Results of Model Studies 57
4.5.1 Fingerprinting 57

4.5.2 Chloride at Urban Intakes 58
4.5.3 DOC at Urban Intakes 59
4.5.4 TTHM at Urban Intakes 61
4.5.5 Bromate at Urban Intakes 63
4.6 Conclusions and Recommendations of Modeling Studies 64
4.6.1 Conclusions 64
4.6.2 Recommendations 65
4.7 DO and Temperature Studies 66
4.7.1 Modeling Approach and Boundary Conditions 66
4.7.2 Project Island DO and Temperature 68
4.7.2.1 Temperature 69
4.7.3.1 Dissolved oxygen 69
4.8 DO and Temperature Requirements 70
4.8.1 Output Location 70
4.9 Simulation Results 70
4.9.1 DO near the Islands 70
4.9.2 Temperature near the Islands 73
4.10 Conclusions and Recommendations of DO and Temperature Studies 73
4.10.1 Conclusions 73
4.10.2 Recommendations 74
4.11 Reservoir Stratification Studies 74

Chapter 5: ENGINEERING INVESTIGATIONS 75

5.1 General 75
5.2 Field Investigations 76
5.2.1 Hydrological Investigations 76
5.2.2 Geologic Explorations 76
5.3 Engineering Design and Analyses 77
5.3.1 Flooding Analysis 77
5.3.2 Embankment Design 78
5.3.2.1 Analysis Parameter 78
5.3.2.2 Erosion, Piping and Seepage Analysis 78
5.3.2.3 Stability Analysis 79
5.3.3 Seismic Analysis 83
5.4 Borrow Area Delineation and Quantity Estimation 84
5.4.1 Field Exploration 84
5.4.2 Laboratory Testing 85
5.4.3 Subsurface Conditions 85
5.4.4 Estimated Available Borrow Volumes 85
5.5 Integrated Facilities Engineering Design and Analyses 86
5.5.1 Components of the Integrated Facility 86

5.6 Construction Methods and Cost Estimation 88
5.6.1 Miscellaneous Costs 90
5.6.2 Cost Contingencies 90
5.6.3 Annual Operation and Maintenance Costs 91
5.7 Risk Analysis 91

Chapter 6: ENVIRONMENTAL EVALUATIONS 93

6.1 General 93
6.2 Land Use 93
6.3 Botanical Resources 93
6.4 Wildlife Resources 94
6.5 Aquatic Resources 94
6.5.1 General 94
6.5.2 Species in the Project Area 95
6.5.3 Fish Screens Design Coordination 96
6.5.4 Shallow Water Habitat Impacts and Mitigation 96
6.6 Cultural Resources 96
6.6.1 Historic Properties Management Plan (HPMP) 97
6.7 Hazardous Materials 98
6.8 Recreation 99
6.9 Mitigation Measures 99
6.10 Findings and Recommendations 100

Chapter 7: ECONOMIC ANALYSIS 101

7.1 General 101
7.2 Methodology 101
7.3 Project Capital Cost 102
7.3.1 Regulatory Costs 102
7.3.2 Forgone Investment Value 102
7.3.3 Annual Cost Development 103
7.4 Assessment of Project Benefits 104
7.4.1 General 104
7.4.2 Urban and Agricultural Water Supply Benefits 105
7.4.2.2 Agricultural Benefits with CVPM Model 108
7.4.3 Estimated Benefits of Other Water Supplies 110
7.4.3.1 CVPIA Level 4 Refuge Supply 110
7.4.3.2 Environmental Water Account (EWA) 110
7.4.3.3 Ecosystem Restoration Program (ERP) Delta Flows 111
7.4.3.4 Groundwater Recharge 111
7.4.3.5 Summary of Estimated Benefits of Other Water Supplies 111
7.4.4 Other Quantified Benefits 111

7.4.4.1 Recreational Benefits 111
7.4.4.2 Avoided Levee Maintenance Cost 112
7.4.4.3 Flooding Risk Benefits 112
7.4.5 Benefits Described in Qualitative Terms 112
7.4.5.1 Delta Benefits 112
7.4.5.2 Carryover Storage 113
7.4.5.3 Wildlife Habitat Improvements 113
7.4.5.4 Interim Banking for Water Transfers Storage 113
7.4.5.5 Seismic Stability Benefits 113
7.4.5.6 Water Quality Improvements 114
7.4.5.7 Value of Operational Flexibility 114
7.4.6 Summary of Project Benefits for Sample Scenarios 115
7.4.7 Potential Benefits Sensitivity Analysis 115
7.5 Delta Economic Impacts 116
7.5.1 Loss of Crop Production 117
7.5.2 Gains from Operations and Maintenance of the Proposed Facilities 119
7.5.3 Recreation Gains 119
7.5.4 Net Local Employment and Income Effects 120
7.5.5 Net Local Sales Tax Revenue Effects 121
7.6 Summary 121

Chapter 8: POLICY AND LEGAL ISSUES 122

8.1 General 122
8.2 Review Process 122
8.3 Permitting Process 122
8.4 Legal Issues 124
8.4.1 CEQA Documentation Required for In-Delta Storage Project 124
8.4.2 DWR Authority to Construct In-Delta Storage Project 126
8.4.3 Other Permits or Legal Requirements Needed for Implementation 127
8.4.4 Potential Liability of Implementing Project 128

APPENDIX A - ABBREVIATIONS AND ACRONYMS 133

APPENDIX B - Review: In-Delta Storage Program CALFED Science Review Public Workshop Report (December 23, 2003) 135

List of Tables

Table 1.1: Project Changes from Initial DW Project to In-Delta Storage Project 2
Table 2.1: In-Delta Storage Project Features 15
Table 3.1: Summary of Results for Sample Operational Scenarios... 29
Table 3.2: Summary of Results for Impact Evaluation Scenarios 30
Table 4.1: Organic Carbon Growth Rates (gC/m2/day) Based on Field Data Analysis................ 51
Table 4.2: DSM2 Project Island Configuration 53
Table 4.3: Project Island Organic Carbon Growth Rates (gC/m2/day) 56
Table 4.4: Summary of Project Island Seepage for Study 4b 57
Table 4.5: Summary of Daily Averaged Chloride (mg/L) at Urban Intakes 58
Table 4.6: Summary of 14-Day Average Chloride (mg/L) at Urban Intakes 59
Table 4.7: Summary of Change in 14-Day Ave. Chloride (mg/L) at Urban Intakes...................... 59
Table 4.8: Summary of 14-Day Average DOC (mg/L) at Urban Intakes...................................... 60
Table 4.9: Summary of Change in 14-Day Ave. DOC (mg/L) at Urban Intakes 61
Table 4.10: Summary of Daily Averaged TTHM (ug/L) at Urban Intakes 61
Table 4.11: Summary of 14-Day Average TTHM (ug/L) at Urban Intakes................................. 62
Table 4.12: Summary of Change in 14-Day TTHM (ug/L) at Urban Intakes 63
Table 4.13: Summary of Daily Averaged Bromate (ug/L) at Urban Intakes................................ 63
Table 4.14: Summary of 14-Day Average Bromate (ug/L) at Urban Intakes 64
Table 4.15: Summary of Change in 14-Day Bromate (ug/L) at Urban Intakes............................ 64
Table 4.16: Summary of Change in Water Quality Constituents for all Urban Intakes 65
Table 4.17: Summary of Violation Period in Water Temperature... 73
Table 5.1: Stability Analysis Results, "Rock Berm" Option [1] (Base of Peat at El. –20 feet)......... 81
Table 5.2: Stability Analysis Results, "Rock Berm" Option [1] (Base of Peat at El. –40 feet)......... 82
Table 5.3: Summary of Available Borrow Volume Estimates 86
Table 5.4: Summary of In-Delta Storage Project Costs.. 92
Table 6.1: Special Status Species for the In-Delta Storage Project 96
Table 6.2: Estimated Initial Environmental Mitigation and monitoring costs............................. 100
Table 6.3: Estimated Annual On-Going Costs for Environmental Mitigation, Monitoring and .. 100
Table 7.1: Forgone Investment Value Adjustment (Millions of 2003 Dollars)........................... 103
Table 7.2: Total Capital and Equivalent Annual Cost Development (2003 $ million) 104
Table 7.3: Summary of Urban Water Supply Deliveries.. 108
Table 7.4: Urban Water Supply Economic Benefits for Sample Scenarios 108
Table 7.5: Summary of Agricultural Water Supply Deliveries 109
Table 7.6: Summary of Agricultural Benefits for Sample Scenarios 110
Table 7.7: Summary of Other Water Supply Deliveries... 111
Table 7.8: Summary of Additional Quantified Water Supply Benefits....................................... 111
Table 7.9: Estimated Recreation Benefits.. 112
Table 7.10: Economic Benefits Summary for Sample Scenarios 115

Table 7.11: Estimated Net Change in Crop Acres Due To Proposed Project.............................. 117
Table 7.12: Local Employment and Employee and Proprietor Income and Employment Effects from Change in Agricultural Production 118
Table 7.13: Local Employment and Employee and Proprietor Income Effects from Operation and Maintenance Expenditures.. 119
Table 7.14: Local Employment and Employee and Proprietor Income Effects from the Discontinuation of Current Levee Maintenance Expenditures.. 119
Table 7.15: Local Employment and Employee and Proprietor Income Effects of Recreation Expenditures 120
Table 7.16: Net Local Employment and Employee and Proprietor Income Effects 120
Table 7.17: Net Local Sales Tax Revenue Effects 121
Table 8.1: Permits and Approvals Required For In-Delta Project.. 130

List of Figures

Figure 1.1: In-Delta Storage Project Islands and Integrated Facility Locations 4
Figure 1.2: In-Delta Storage Program Organization 6
Figure 2.1: Webb Tract Storage and Integrated Facilities 12
Figure 2.2: Bacon Island Storage and Integrated Facilities 13
Figure 2.3: Rock Berm and Bench Options for Embankments 14
Figure 2.4: Typical Integrated facility 3-Dimensional View 14
Figure 3.1: 1995 Water Quality Control Plan (D1641) Requirements 18
Figure 3.2: D1643 Constraints in the Delta Wetlands Properties Permit 20
Figure 3.3: Water Supply Reliability 31
Figure 3.4: Long-Term Average Annual Change in Water Supply 32
Figure 3.5: Long-Term Oroville Carryover Storage 33
Figure 3.6: In-Delta Storage Supply Contribution to EWA 34
Figure 3.7: Dedicated In-Delta Storage Supply Contribution to ERP 35
Figure 3.8: Bacon Island Operations in Below Normal Year - Study 4b 36
Figure 3.9: Webb Tract Operations in Below Normal Year - Study 4b 37
Figure 3.10: Long-Term Monthly Average Diversions for Storage – Study 4b 37
Figure 3.11: Long-Term Monthly Average Diversions for Circulation – Study 4b 38
Figure 3.12: Long-Term Monthly Average Operational Releases from IDS – Study 4b 38
Figure 3.13: Long-Term Average Annual SWP/CVP Deliveries with Climate Change 40
Figure 3.14: Long-Term Average Annual Changes in Water Supply 41
Figure 4.1: View of Nine Fiberglass Tanks Used to Create Mesocosms 46
Figure 4.2: Mean 2002 DOC Concentrations in Mesocosms 48
Figure 4.3: Mean 2003 DOC Concentrations in Mesocosms 49
Figure 4.4: Mean 2003 March-July Storage Period DOC Concentrations in Mesocosms 49
Figure 4.5: Mean 2003 Winter DOC Concentrations in Mesocosms 50
Figure 4.6: Mean 2003 Drained Period DOC Concentrations in Mesocosms 50
Figure 4.7: Study Methodology for Modeling 52
Figure 4.8: DSM2 Grid Surrounding Bacon Island and Webb Tract. 54
Figure 4.9: WQMP Incremental DOC Constraint. 60
Figure 4.10: WQMP Incremental TTHM Constraint 62
Figure 4.11: Study Methodology 67
Figure 4.12: DO and Interaction among Water Quality Parameters 68
Figure 4.13: Representation of Webb Tract and Bacon Islands in DSM2 71
Figure 4.14: Bar Plot of Channel DO Differences with and without Project (High chlorophyll) .. 72
Figure 4.15: Sensitivity of DO for High and Intermediate Chlorophyll Scenarios 72
Figure 4.16: Bar Plot of Channel DO Differences with and without Project (Intermediate) 73
Figure 5.1: Engineering Investigations Flow Chart 75
Figure 5.2: Conceptual Details for Typical Embankment 80

Figure 5.3: Typical Integrated Facility Layout 88
Figure 7.1: Conceptual Diagram of LCPSIM Urban Economic Model 105
Figure 7.2: CVPM Agricultural Economics Model Logic... 108
Figure 7.3: Sensitivity Analysis for South Coast Management Options Assumptions 116
Figure 8.1: In-Delta Storage Program Review Process 132

List of Feasibility Study Reports

1. DWR, January 2004, Draft Executive Summary.
2. DWR, January 2004, Draft Summary Report.
3. DWR, December 2003, Draft Report on Operations.
4. DWR, December 2003, Draft Report on Water Quality Investigations.
5. DWR, July 2003, Draft Report on Environmental Evaluations.
6. DWR, January 2004, Draft Report on Economic Analyses.
7. DWR, July 2003, Draft Engineering Investigations Summary.
8. URS Corporation, June 2003, Embankment Design Analysis, Draft Report.
9. URS Corporation, June 2003, Flooding Analysis, Draft Report.
10. URS Corporation, June 2003, Seismic Analysis, Draft Report.
11. URS Corporation, April 2003, Borrow Area Geotechnical Draft Report.
12. DWR and URS Corporation, July 2003, Integrated Facilities Engineering Design and Analyses, Draft Report.
13. URS Corporation, June 2003, In-Delta Storage Program Earthwork Construction Cost Estimate, Draft Report.
14. URS Corporation, June 2003, In-Delta Storage Program Integrated Facilities Structures Construction Cost Estimate, Draft Report.
15. URS Corporation, June 2003, In-Delta Storage Program Risk Analysis, Draft Report.
16. DWR January 2003, Results of Geologic Exploration Program, Final Report.
17. DWR January 2003, Results of Laboratory Testing Program, Final Report.

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Chapter 1: GENERAL

1.1 Introduction

In 2001, the California Department of Water Resources (DWR) and the CALFED Bay-Delta Program, with technical assistance from the U.S. Bureau of Reclamation (Reclamation), initiated a joint planning study to evaluate the Delta Wetlands Project and other in-Delta storage options for contributing to California Bay-Delta Program's water supply reliability and ecosystem restoration objectives. The main purpose of these investigations was to determine if the proposed DW Project was technically and financially feasible. The joint planning study, which was completed in May 2002, concluded that the project concepts as proposed by Delta Wetlands were generally well planned. However, project modifications and further evaluations were needed before considering public ownership of the project. Based on initial work completed by DWR and Reclamation, in June 2002 the Bay-Delta Public Advisory Committee recommended that Bay-Delta Agencies complete additional evaluations and address several outstanding issues before considering implementation of the In-Delta Storage Project. This Draft Summary Report summarizes findings of the State Feasibility Study evaluations conducted by DWR since June 2002. DWR presents these findings as a neutral technical evaluator of the costs, benefits, impacts, and uncertainties associated with a publicly owned In-Delta Storage Project.

The State Feasibility Study objective is to:

- provide technical and financial information to the CBDA and Bay-Delta agencies, that will decide if the project can be implemented with an acceptable level of risk; and
- provide water supply reliability and ecosystem restoration benefits at a reasonable cost.

The criteria to be used for State feasibility level determination were established during discussions of the DWR Independent Board of Consultants meeting in May 2003. The general guideline included:

- no major changes or surprises in the project design and costs as the project moves into final design, construction, and operation; and
- no possibility of fatal flaws in the project that would jeopardize the project implementation.

Delta Wetlands made the original proposal in July 1987 for storage on Webb Tract and Bacon Island with habitat development on Holland Tract and Bouldin Island. The State Water Resources Control Board (SWRCB) issued the water rights permit in February 2001, subject to meeting State and federal standards. SWRCB approved water quality certification under the Clean Water Act Section 401 on September 20, 2001. The Section 404 Application to the United States Army Corps of Engineers (USACOE) was approved in 2002.

The In-Delta Storage Project includes the same islands as the DW Project - storage on Webb Tract and Bacon Island with Holland Tract and Bouldin Island as habitat islands for impact mitigation (Figure 1.1). However, the In-Delta Storage Project design differs from the DW Project by incorporating into the project:

- new embankment design and four consolidated inlet and outlet structures;
- new project operations;
- resolving local water quality issues through field experimentation and modeling;
- revised Habitat Management Plans; and
- detailed risk and economic analysis

Changes from initial DW Project to the new In-Delta Storage Project are shown in Table 1.1.

Table 1.1: Project Changes from Initial DW Project to In-Delta Storage Project

Features	Delta Wetlands	In-Delta Storage
1. Engineering Embankment Design Structures Fish Screens	Existing Levees with added fill, slough rock No Risk Analysis Factor of Safety (FOS) 1.2-1.3 Pipe siphons 99 Pumps 72 Fish Screens Barrel Type 99	Composite Design: Rock Berm and Bench Acceptable Risk FOS 1.5 Four Integrated Facilities Flat screens with louvers and cleaning devices (Los Vaqueros Type)
2. Operations	Gaming Exercises with Spreadsheet using DWR Simulation Model (DWRSIM) Outflows and unlimited demand without system-wide evaluation. Reservoir outflow as yield	Part of SWP/CVP System California Simulation Model (CALSIM), Delta Simulation Model (DSM2), Particle Tracking (PT) and Dynamic Reservoir Simulation (DYRESM) models Reiterations. - Delta requirements - Exports & Carryover - Environmental Water Account (EWA) and Ecosystem Restoration Program (ERP) - Water Quality and Fisheries
3. Water Quality	No State Water Resources Control Board Decision 1643 and California Urban Water Agencies Water Quality Management Plan Evaluations	Resolving issues: - Field experimentation - Organic Carbon issue with dispersion and circulation techniques - Temperature and Dissolved Oxygen Stratification - Water Quality improvements
4. Environmental	Extensive evaluations done and Habitat Management Plan prepared.	Habitat Management Plan revised with new resource information and In-Delta impacts.
5. Economic Analysis	No analysis	Economic models used in analysis

The Summary Report presents information on studies and investigations conducted during the State feasibility phase of the In-Delta Storage Program. Chapter 1 describes the general overview of the directive for the feasibility study, institutional arrangements under the recently established California Bay-Delta Authority (CBDA), role of storage in the Delta ecosystem, feasibility study management and coordination between agencies and summary of the findings. Chapter 2 provides information on how this study is linked to the CALFED Programmatic EIR/EIS Process – the progression of the study from the original conceptual stage through planning phase and to the State feasibility stage and the description of the In-Delta Storage Project including major changes and salient features of the project.

The project operations criteria and scenarios evaluated for regional and system-wide benefits are presented in Chapter 3. Information on coordinated operations with SWP and CVP and operations to resolve organic carbon issues are presented in this chapter. Chapter 4 describes the existing water quality requirements, new constraints on the project under D1643, biological and ecological processes in the Delta, field investigations, modeling and reservoir stratification studies to check compliance of standards for water quality evaluations.

Chapter 5 describes the engineering investigations including geotechnical explorations, flooding erosion, piping, seepage, as well as seismic and risk analysis for embankment design. Integrated facilities design includes hydraulic, structural, mechanical and electrical design. Borrow area investigations were conducted for borrow materials and on the basis of construction methods and market suppliers detailed cost estimates were also prepared for the project. Under environmental evaluations in Chapter 6, studies were conducted to evaluate the project's impact and mitigation requirements on the affected resource categories in the Delta. Chapter 7 describes the methodology used for economic analysis to determine the project benefits and regional impacts in monetary terms. Chapter 8 deals with the project reviews by CALFED agencies, the public, and explains policy and legal issues for implementation.

1.2 Role of Storage in Delta Ecosystem and Water Supplies

The mission of the CALFED Bay-Delta Program is to develop a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses of the Bay-Delta system. The following objectives were developed for a solution.

- Provide good water quality for all beneficial uses.
- Improve aquatic and terrestrial habitats and ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species.
- Reduce the mismatch between Bay-Delta water supplies and current and projected beneficial uses dependent on the Bay-Delta system.
- Reduce the risk to land use and associated economic activities, water supply, infrastructure and the ecosystem from catastrophic breaching of Delta levees.

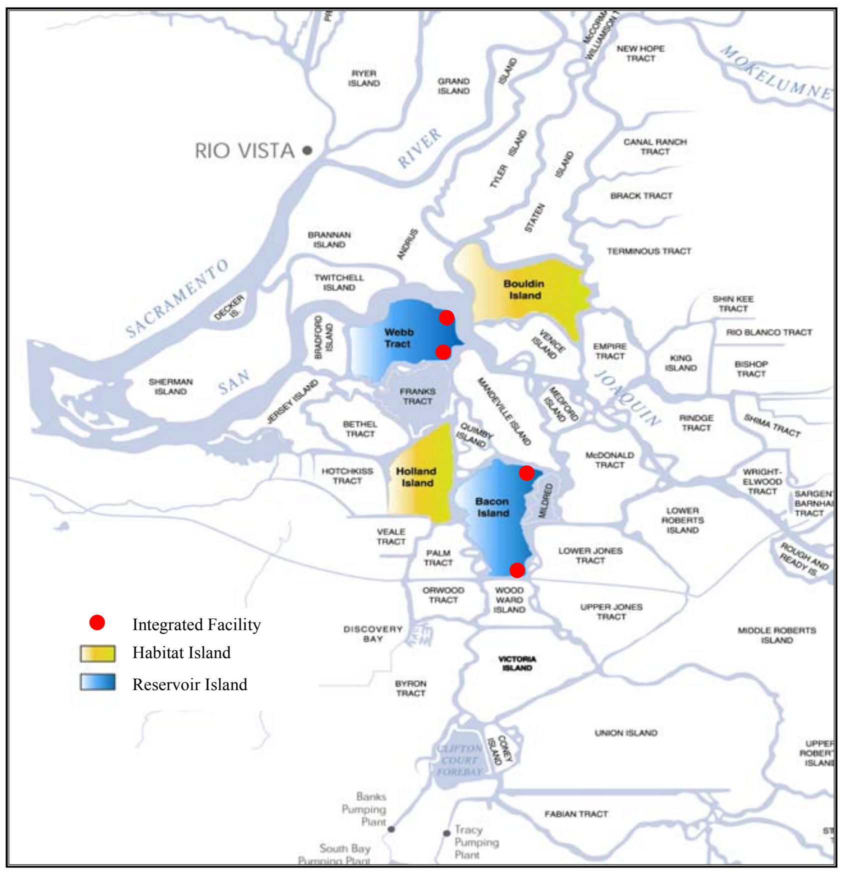
In the context of the CALFED mission to develop a comprehensive plan, the role of in-Delta storage is to help meet the ecosystem needs of the Delta, Environmental Water Account (EWA) and Central Valley Project Improvement Act (CVPIA) goals, provide water for use within the Delta and increase reliability, operational flexibility and water availability for south of the Delta water use by the State Water Project (SWP) and the Central Valley Project (CVP).

New storage in the Delta could be useful to the California water system. Improved operational flexibility would be achieved by providing an opportunity to change the timing of Delta exports at new points of diversion that could be selectively used to minimize impacts on fish. The project would divert water from the Delta to In-Delta storage with state of the art fish screens and in a manner to reduce impacts to fish species of concern. The stored water would allow curtailing export diversion at times most critical to the listed aquatic species.

In-Delta storage can:

- increase water supply reliability;
- improve system operational flexibility by making required releases for urgent needs;
- allow reservoir space to be temporarily used for water transfers and banking;
- allow water to be stored and released to meet CVPIA and EWA goals and water quality constraints; and
- allow surplus water to be stored during wet periods and when upstream reservoirs spill, permitting water to be stored in the Delta and released into the San Joaquin River and other in-stream channels for fisheries during dry periods.

Figure 1.1: In-Delta Storage Project Islands and Integrated Facility Locations



The role of the habitat islands goes beyond mitigation as it would make improvements to the existing habitat by developing and protecting 9,000 acres of agricultural and wetlands on Holland Tract and Bouldin Island. A Habitat Management Plan (HMP) will guide the development of habitat that will compensate for the loss of foraging habitat for endangered species like Swainson's hawk and greater sandhill crane, jurisdictional wetlands and wintering waterfowl habitat. A conjunctive agricultural-wildlife friendly HMP will include modifications to agriculture crops, seasonal managed wetlands, pasture, emergent marsh and other habitat types.

Due to the project’s strategic location, the operation of the island reservoirs would contribute to an incremental improvement in habitat quality and availability for fish and other aquatic organisms inhabiting the Bay-Delta system. A coordinated approach of the CALFED Storage and

Environmental Restoration Programs is required to achieve the long-term restoration goals in the region.

1.3 Feasibility Study Management and Coordination

1.3.1 Institutional Setting

Effective January 1, 2003, a new State agency has formally assumed responsibility for overseeing implementation of the Bay-Delta Program. The California Bay-Delta Authority (Authority), established by the California State Legislation by enactment of Senate Bill 1653 (Costa) of 2002, provides a permanent governance structure for the collaborative State-federal effort that began in 1994. Prior to January 1, 2003 implementation of the Bay-Delta Program was overseen by CALFED.

The Authority is composed of representatives from six state agencies, six federal agencies, five public members from the program's five regions, two at-large public members, a representative from the BDPAC, and four ex officio members (namely the chairs and vice-chairs of the Senate and Assembly water committees).

Housed within the California Resources Agency, the Authority is charged specifically with ensuring balanced implementation of the Program, providing accountability to the Legislature, Congress, the public, and ensuring the use of sound science across all Program areas.

Feasibility study management and coordination process has two levels of participation.

- The Authority assumes management level responsibility for policy direction and overall coordination of the Storage Program. The Authority assesses program progress and provides program direction and is also responsible for oversight and coordination between agencies. BDPAC WSS provides advice and recommendations on the storage program planning.

- The Department of Water Resources is the lead agency for the feasibility study and California Environmental Quality Act (CEQA) compliance. Reclamation is the lead agency for National Environmental Policy Act (NEPA) compliance. Because Reclamation does not have congressional authority to participate in a federal feasibility study, their participation has been limited to technical assistance.

These two levels of participation are shown in Figure 1.2. The In-Delta Storage Program management is organized in a way to provide technical coordination between agencies and allow technical staff to contribute to various components of the program.

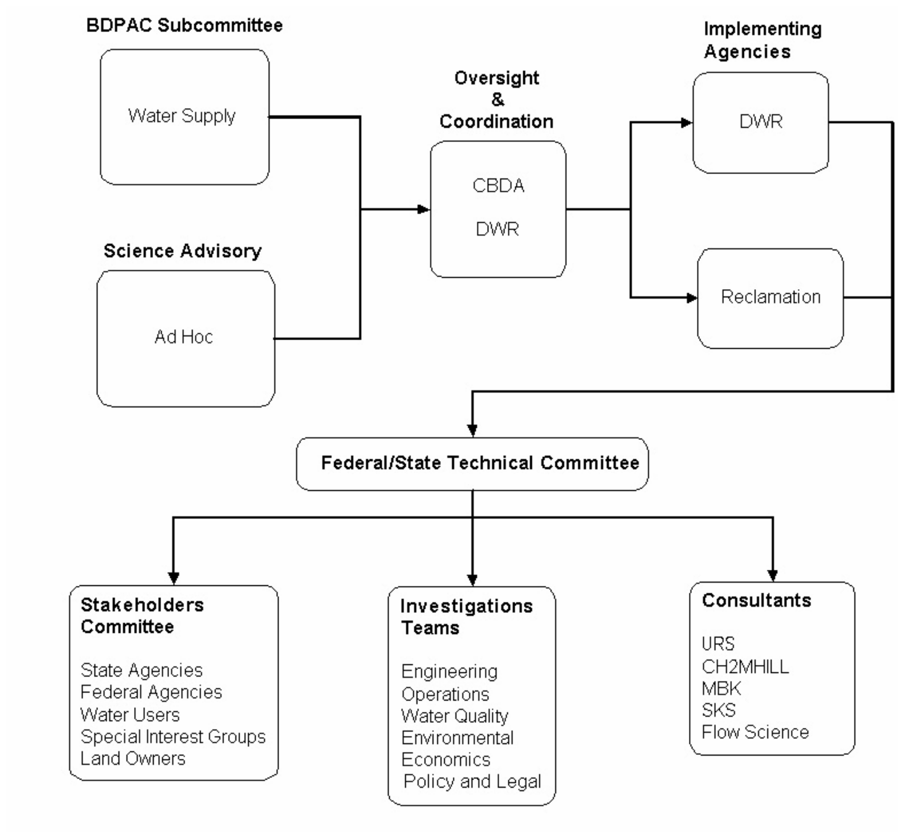
1.3.2 Public Outreach

Public outreach is a process which allows interested and affected individuals, organizations, agencies and governmental entities to be informed of a project's goals, objectives, status and have the opportunity to participate in the planning process by sharing and exchanging technical and policy information. Public outreach supports the exchange of ideas, information, and concerns among individuals and groups which is critical to the evaluation of In-Delta Storage Project. CALFED's Record of Decision on consultation states that CALFED agencies will actively engage federally recognized tribal governments in the project planning and will formally consult with such tribes on a government-to-government basis.

Public outreach also creates and builds partnerships, involves the communities (including local water interest and stakeholder groups, state and federal agencies, Tribes, the general public, and elected officials), helps form mutual understanding, reduces conflict, and ensures that public input is fully considered.

In-Delta Storage Program public outreach effort is implemented through the Stakeholders Committee that has participation of 60 agencies and Delta landowners. Also, all communications are sent to tribal and other groups. In the last three years of the program, Stakeholders Committee meetings have been held at various locations in the Delta and at Sacramento.

Figure 1.2: In-Delta Storage Program Organization



Through public outreach the In-Delta Storage Program plans to:

- increase public awareness of in-Delta storage objectives and the role and significance of In-Delta storage to help achieve the overall CBDA objectives;
- inform and consult with the public on the technical studies;
- involve stakeholders, agencies, Tribes, and other interested groups and individuals as the environmental document is developed to ensure that public values and input are fully considered;
- reduce conflict among interested and affected parties by building agreement on solutions to emerging issues; and
- improve the quality of project-level decisions as a result of public participation.

Outreach efforts must go beyond simply informing the public. Outreach efforts should seek to involve interested people in the entire planning process. Public involvement can be achieved through public hearings, meetings or workshops. Notices for public outreach activities are distributed through mailing list of interested individuals and groups including elected officials, local landowners, business organizations, environmental groups, local water agencies, agricultural groups, Tribes, and recreational groups.

1.4 Summary of Findings

- Based on the study evaluations (operations, water quality, engineering, environmental and economic) and engineering design review by the IBC (Report No. 2 dated May 30, 2003), the In-Delta Storage Project construction and operation are feasible with an acceptable level of risk of structural failure and minimal potential for loss-of-life. The total capital cost of the project, including construction, engineering, legal, administration, permitting, land acquisition, relocations, and allowance for contingencies is estimated to be approximately $774 million. This capital cost translates into an equivalent annual cost of approximately $60 million, including annual operation and maintenance costs.

- In-Delta Storage could be operated in a wide variety of ways to produce differing benefits. To provide information about the types and magnitudes of potential benefits, DWR evaluated three sample operating scenarios. These scenarios emphasized combinations of the following operational priorities: deliveries to urban and agricultural water users, assets for the Environmental Water Account, and contributions to the Environmental Restoration Program Delta flow targets. Total long-term average annual water supply improvements provided by In-Delta Storage under these scenarios ranged from 124 to 136 TAF. Total average annual water supply improvements during dry periods ranged from 59 to 62 TAF. See Chapter 3 for details on the assumptions used in these evaluation and information on possible constraints to operations that were not considered in this evaluation. In addition to these water supply improvements, In-Delta storage could also provide other benefits that have not yet been quantified, such as additional system operational flexibility, water quality improvements, wildlife and habitat improvements and seismic stability for Delta levees.

- The Department's preliminary benefits analysis conservatively values the annual water supply benefits at approximately $23 to 26 million. This estimate is extremely sensitive to assumptions about the future cost and availability of other water management options (e.g., conservation, wastewater recycling, groundwater reclamation etc.) and should be refined in consultation with potential beneficiaries and economic experts. DWR estimates that an additional $2 million in annual benefits would be associated with the recreation, flood damage reduction and avoided levee maintenance provided by the project. In addition, the project might provide other benefits, such as operational flexibility, water quality improvements, wildlife and habitat improvements and seismic stability. Before total project benefits and cost can be compared, value must be assigned to these benefits. The Department will work with the Bay-Delta Public Advisory Committee and the California Bay-Delta Authority to gather input from interested parties before completing this benefits assessment.

- Due to the project's strategic location, the operation of the island reservoirs would contribute to an incremental improvement in habitat quality and availability for fish and other aquatic organisms inhabiting the Bay-Delta system. The timing of environmental water allocations would be flexible depending on the specific environmental benefit to be achieved (e.g. protection of spring-run chinook salmon and delta smelt). Due to the possibility of increased carryover storage in the upstream SWP and CVP reservoirs as a result of storing water in the Delta, CALFED's ERP and storage programs should work closely with regulatory agencies to maximize the program benefits and assure compliance of the Endangered Species Act.

- Environmental Water Account studies for the In-Delta Storage Project support EWA benefits for two options: a dedicated release from Bacon Island to supply water for the SWP and CVP pumping curtailments without direct connection to Clifton Court Forebay (CCF), or a firm delivery with direct connection to CCF. A direct connection to CCF using a pipeline would provide "fish free" water, because the water was screened using state-of-the-art fish screens on Bacon Island and would support the Conveyance Program's goal to screen CCF up to 10,300 cfs.

- The seismic risk of implementation cannot be avoided, but the design recommended for this project is better than other Delta island levees and is similar to the design criteria used for other projects in the Delta (e.g. Clifton Court Forebay, Delta Cross Channel, etc.). It is essential that efforts to reduce seismic risk to other Delta islands through Delta levee improvements continue and emergency response measures are developed. These efforts should proceed in coordination with the In Delta Storage Program. This linkage is necessary for public health and safety and for the protection of any future infrastructure investments in the Delta. Levees that fail can also threaten the water quality of In-Delta storage, Delta agriculture, and three major water diverters: the SWP, the CVP, and Contra Costa Water District (CCWD).

- The In-Delta Storage Project and the Los Vaqueros Expansion Project were modeled, and evaluation indicates that both projects can be operated in coordination. Further evaluation of shared diversion points may result in additional benefits and cost savings. Comparative information on the other three CALFED storage programs (Shasta Enlargement, North of Delta Offstream Storage and storage in the upper San Joaquin River Basin), could not be completed within the time limits of this study. Comparative information on other four storage programs based on daily modeling and refined operational scenarios is required (not yet developed) to evaluate the benefits of joint operations. As these projects are at different levels of study development, future evaluations should be made based on common assumptions and developed operational scenarios.

- Global warming and sea level rise issues have been studied as part of the In-Delta Storage Program using a revised climate change hydrology. The proposed embankments annual operations and maintenance costs include accommodating potential sea level rise due to climate change over the next 50 years assumed life period of the In-Delta Storage Project. Climate change may result in higher winter flows and reduced spring runoff. Operation studies indicate that effect of climate change on In-Delta Storage operations would result in marginal change in water supplies.

1.5 Potential Future Actions

If CBDA and DWR determine that additional studies on the In-Delta Storage investigations are warranted, that work should include:

- Additional water quality field and modeling evaluations are necessary to refine project operations for organic carbon, dissolved oxygen and temperature. The recent studies indicate that circulating fresh water through the reservoirs could be effective mitigation to resolve the organic carbon issue. A final field investigations and modeling plan should be developed with recommendations from the CALFED Science Panel Review.

- Any future steps on the In-Delta Storage Investigation should include refinement of the operational and economic analyses. This refinement should consider uncertainty in future operations at the State Water Project's Banks Pumping Plant, the OCAP, and other important CALFED Program actions that are being studied simultaneously. Also, DWR should work with economic experts and stakeholders to improve the assumptions in the economic models and quantify all of the benefits discussed in this report for a better numerical comparison of benefits and costs.

- Subsequent CEQA/NEPA documents would be required because of three key revisions to the project that are different than those stated in the SWRCB Decision 1643: 1) the project requires purchase of private lands for public development; 2) the In-Delta Storage Project's operations will now be coordinated with the SWP or CVP system operations; 3) DWR recommends changes in the project diversion locations.

- Future CEQA/NEPA evaluations will tier from the CALFED 2000 Final Programmatic EIR/EIS to meet the CALFED water supply reliability and ecosystem restoration objectives and overall benefits and impacts should be evaluated with due consideration to the strategic planning of the CALFED Bay-Delta Program long-term plan. Future CEQA/NEPA evaluations will also take full advantage of the 2002 Final EIR and EIS completed for the Delta Wetlands Project in order to minimize the time and cost of such review.

- A detailed engineering and economic analysis of a direct connection to CCF using a pipeline or an alternative conveyance is recommended to evaluate possible savings in fish screening structures being proposed for the new CCF intake.

Chapter 2: PROJECT BACKGROUND

2.1 Link to CALFED Programmatic EIR/EIS Process

In July 2000, CALFED completed its Final Programmatic EIS/EIR. The Programmatic EIR/EIS takes a broad approach to addressing the four problem areas of water quality, ecosystem quality, water supply reliability and levee system integrity, recognizing that many of the problems and solutions in the Bay-Delta system are interrelated. Problems in any one program area cannot be solved effectively without addressing problems in all four areas at once. This greatly increases the scope of efforts but will ultimately result in progress toward a lasting solution.

Thus, the single most important difference between the CALFED Bay-Delta Program and past efforts to solve the problems of the Bay-Delta is the comprehensive nature of CALFED's interrelated resource management strategies. Any solution must satisfy the following solution principles:

- ***Reduce Conflicts in the System*** Solutions will reduce major conflicts among beneficial uses of water.
- ***Be Equitable*** Solutions will focus on solving problems in all problem areas. Improvements for some problems will not be made without corresponding improvements for other problems.
- ***Be Affordable*** Solutions will be implementable and maintainable within the foreseeable resources of the Program and stakeholders.
- ***Be Durable*** Solutions will have political and economic staying power and will sustain the resources they were designed to protect and enhance.
- ***Be Implementable*** Solutions will have broad public acceptance and legal feasibility, and will be timely and relatively simple to implement compared with other alternatives.
- ***Have No Significant Redirected Impacts*** Solutions will not solve problems in the Bay-Delta system by redirecting significant negative impacts, when viewed in their entirety, within the Bay-Delta or to other regions of California.

The twelve program solution components include Governance, Ecosystem Restoration, Watersheds, Water Supply Reliability, Storage, Conveyance, EWA, Water Use Efficiency, Water Quality, Water Transfers, Levees, and Science. There is significant overlap and need for coordination between component programs. For example, the In-Delta Storage Project preferred alternative will likely include ecosystem restoration, water supply reliability, storage, environmental water account, water quality, Delta levee, and science program components explicitly. Expanding water storage capacity, in particular, is critical to the successful implementation of all aspects of the CALFED Program. Not only is additional storage needed to meet the needs of a growing population but, if strategically located, it will provide much needed flexibility in the system to improve water quality and support fish restoration efforts. The Final Programmatic EIS/EIR identified 12 potential surface reservoir sites and many possible groundwater storage sites. The Record of Decision (ROD) directed DWR and Reclamation to work with other CALFED Agencies and pursue expansion of two existing reservoirs (Enlarged Shasta and Expanded Los Vaqueros) and construction of a new offstream reservoir (In-Delta Storage), with a combined capacity of 950 TAF. In addition, two other storage projects, North-of-the-Delta offstream storage and Upper San Joaquin River Basin Storage Investigations, are being studied as directed by the ROD. Expansion of an additional 500 TAF to 1 MAF of groundwater storage was also included in the ROD direction.

As a part of the In-Delta Storage Investigations, CALFED Agencies also decided to explore the lease or purchase of the DW Project, a private proposal by DW Properties Inc. to develop and market a water storage facility in the Sacramento-San Joaquin Delta (Delta). The ROD included an option to initiate a new project if the DW Project proves cost prohibitive or technically infeasible. The following deadlines were established for the In-Delta Storage Program:

- Make decision whether to seek authorization for a feasibility study of alternatives (federal funds) by October 2000.
- Select project alternative and initiate negotiations with DW owners or other appropriate landowners for acquisition of necessary property by December 2001.
- Develop project plan that addresses local concerns about effects on neighboring lands and complete any additional needed environmental documentation by July 2002.
- Complete environmental review and documentation, obtain necessary authorization and funding, and begin construction by the end of 2002.

In order to address the first deadline, DWR and Reclamation completed appraisal level studies of the DW Project and other alternatives and presented results in a joint report titled "Summary Appraisal Report, Reclamation/DWR In-Delta Storage Investigations" (November, 2000). This appraisal concluded that the DW Project could provide improved operational flexibility, unique to in-Delta storage, in meeting CALFED objectives by storing in-stream flow releases from upstream reservoirs to later meet Delta outflow requirements and enhance water reliability. In 2001, the appraisal studies were followed by a joint planning study concluding in May 2002 In-Delta Storage Program Summary Report prepared by DWR and the CALFED Bay-Delta Program, with technical assistance from the U.S. Bureau of Reclamation. The State Feasibility Study was recommended on the basis of findings of the joint planning study.

2.2 Study Progression from Planning to Feasibility Level

The previous appraisal and planning studies were mainly associated with evaluation of the DW proposal and all assessments were based on application of SWRCB permit requirements as a private development. As a public owned project, In-Delta Storage if managed by CALFED agencies will become a part of the SWP and CVP system. For the State feasibility study, In-Delta Storage reservoirs will be operated as a State and/or Federal owned project and diversions and releases will be made under existing regulations such as the SWRCB decisions D1641 (Delta Water Quality Management Plan) and D1643 (DW Permit Water Quality and Fisheries Requirements) applicable requirements. The SWP and CVP operations will also meet all the Coordinated Operations Agreement (COA) requirements. As some of the D1643 requirements may not apply to SWP/CVP operations, the SWRCB permit may need to be revisited. Also, there may be changes in diversion point's locations as in the re-engineered In-Delta Storage Project water diversion for Bacon Island has been changed from Old River to Santa Fe Cut. This may change environmental impacts and the SWRCB will be requested to allow revisions in the existing DW Permit.

In the State Feasibility Study, the main differences between the DW Project and the In-Delta Storage Project are in the reservoir operations, design of engineering works and evaluations for water quality, environmental and economic analysis as presented in Table 1.1.

2.3 Project Description

The DWR/CALFED joint planning study with technical assistance from Reclamation May 2002 In-Delta Storage Program Summary Report made a number of recommendations, one of which was that "solutions should be developed to enhance project reliability through improved design and consolidation of inlet and outlet structures". The proposed In-Delta Storage Project consists of two reservoir islands (Webb Tract and Bacon Island), two habitat islands (Holland Tract and Bouldin Island) and four integrated facilities (two structures on each of the storage islands) as shown in Figures 2.1 and 2.2. A total of 217 TAF of storage is to be created by either strengthening existing levees or building new embankments inside the existing levees.

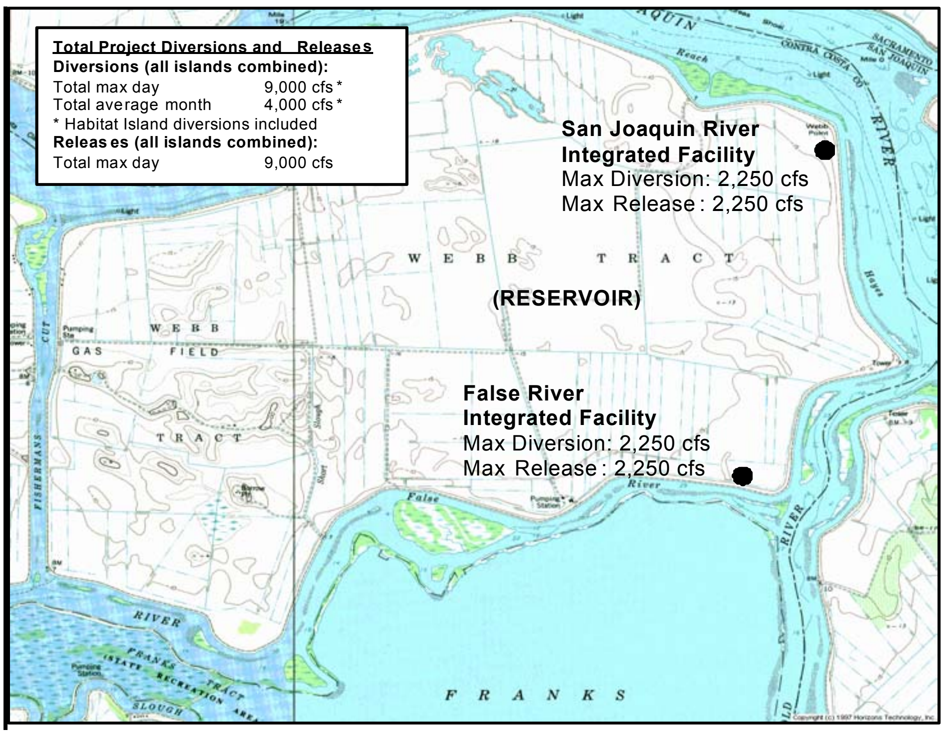


Figure 2.1: Webb Tract Storage and Integrated Facilities

The maximum permitted diversion onto the reservoir islands and habitat islands is 9,000 cubic feet per second (cfs). The maximum allowable release is not mentioned in the permit. However, maximum annual storage that can be released with alternative fill and release operations is 822 TAF. In this study analysis was performed with assumed maximum diversions of 9,000 cfs and 6,000 cfs and total structural capacity for 9,000 cfs release was provided from two islands for evaluation. The proposed seasonal diversions onto "habitat islands" are intended for wetlands and wildlife management, and enhancement for environmental mitigation. Pertinent features of the In-Delta Storage Project are given in Table 2.1.

2.3.1 Embankments

Two configurations of engineered embankments are proposed for the reservoir islands, Rock Berm and Bench configurations (Figure 2.3). There are geometric (oversteepend slopes due to scour or dredging) and environmental difficulties which require use of alternative configurations. In the Rock Berm option, additional rock fill would be placed on the slough side and new fill will be added to the existing levee on the crest and the island side to achieve the minimum required factor of safety. In the Bench option, the crest of the existing levee would be lowered and new fill would be placed on the island side of the lowered crest. The existing levee's lowered crest becomes the bench on the slough side.

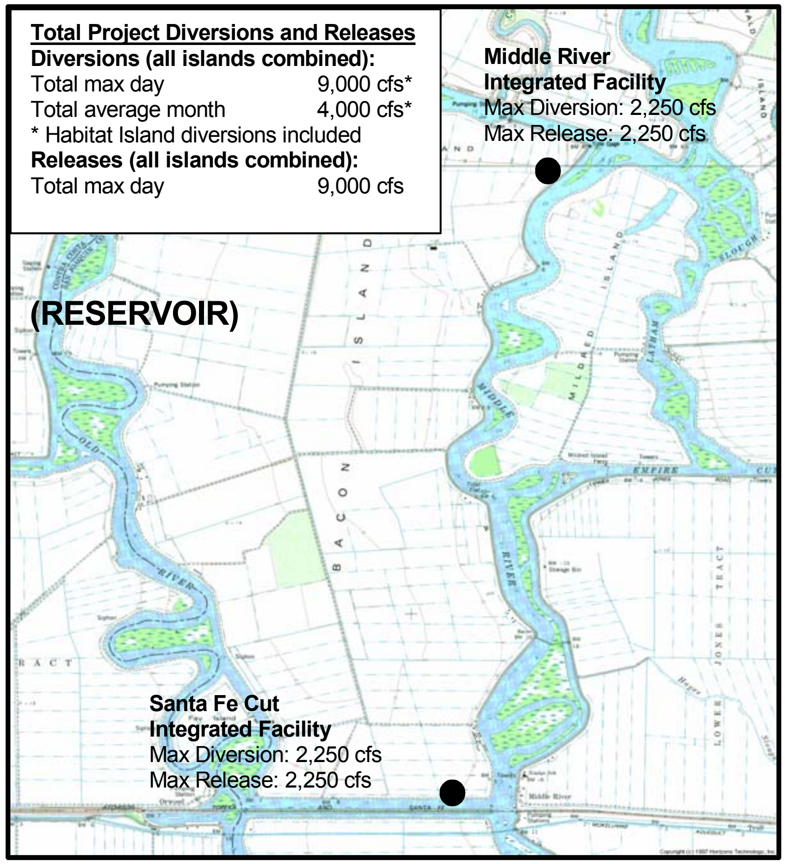


Figure 2.2: Bacon Island Storage and Integrated Facilities

2.3.2 Integrated Facilities

There are a total of four integrated facilities, two on Webb Tract and two on Bacon Island. The facilities will be used to control the diversion and release of water onto and off of the reservoir islands. The integrated facilities are consolidated control structures that combine all operational components into one facility (Figure 2.4). The operational goal of the integrated facility operations is to maximize gravity flow and minimize pumping to reduce operation and maintenance cost.

The operational components of each facility necessary for a reliable and cost effective operation that meet the operational goal include a state-of-the-art fish screen, a transition pool, three inlet/outlet structures, a midbay, a pumping plant and associated conduit, a bypass channel, and engineered embankments.

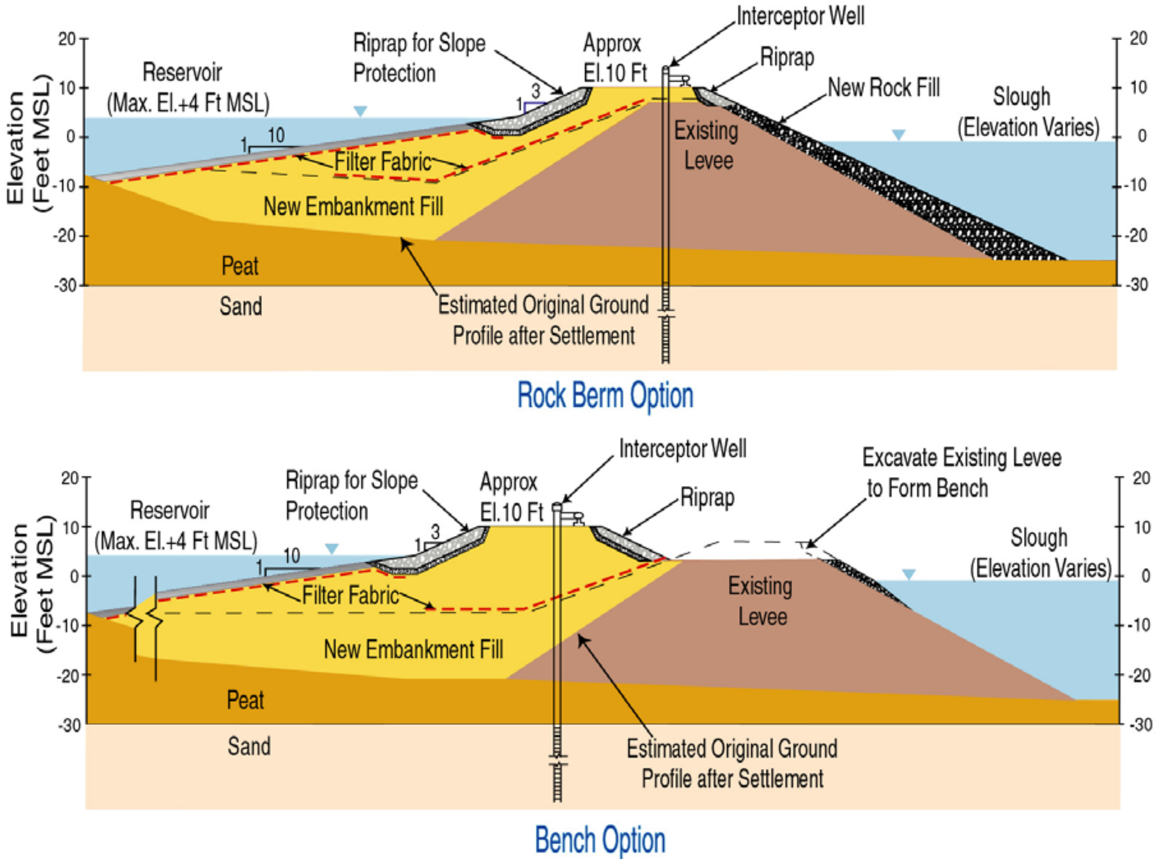


Figure 2.3: Rock Berm and Bench Options for Embankments

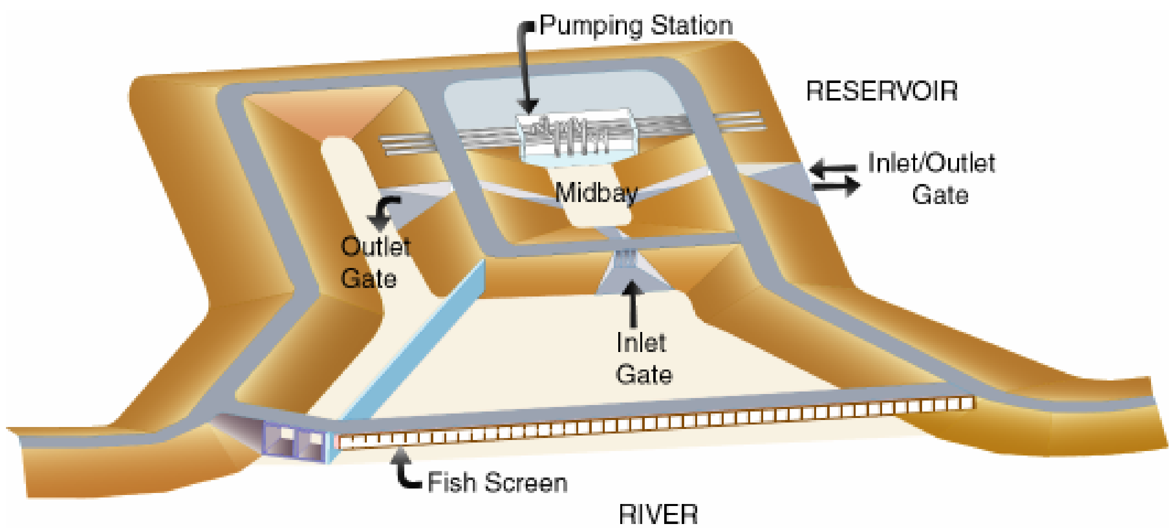


Figure 2.4: Typical Integrated facility 3-Dimensional View

Table 2.1: In-Delta Storage Project Features

Item	Bacon Island		Webb Tract	
Reservoir				
Area (acres)	5,470		5,390	
Storage (ac-ft)	116,000		101,000	
Max. Level (ft. above msl)	+4		+4	
Embankments				
Length (miles)	14.20		12.88	
Crest Width (feet)	35.0		35.0	
Top of Embankment (El. ft)	10.1		10.3	
Slopes – Slough Side	3:1 (Crest to +4)		3:1 (Crest to +4)	
– Reservoir Side	10:1 (+4 to Bottom)		10:1 (+4 to Bottom)	
Erosion Protection – Slough	Rock		Rock	
- Reservoir	Rip Rap on 3:1 all sides up to +3 El and Soil Cement on 10:1 (N & W Facing)		Rip Rap on 3:1all sides up to +3 El and Soil Cement on 10:1 (N & W Facing)	
Seepage Control	Interceptor Wells		Interceptor Wells	
Integrated Facility				
Name	Middle River	Santa Fe	San Joaquin	False River
Fish Screens				
Number of Bays	40	51	40	33
Length of Screens (ft)	800	1020	800	660
Total Width (ft.)	878	1120	878	724
Gated Structures				
Design Inflow (cfs)	2250	2250	2250	2250
Design Outflow (cfs)	2250	2250	2250	2250
Inlet (River to Midbay)	3 Gates-12x10	3 Gates- 12x10	3 Gates- 12x10	3 Gates-12x10
Inlet/Outlet (Reservoir/Midbay)	3 Gates-12x10	3 Gates-12x10	3 Gates-12x10	3 Gates-12x10
Outlet (Midbay to Bypass)	2 Gates-12x8	2 Gates-12x8	2 Gates-12x8	2 Gates-12x8
Pumping Plants				
No. of Pumps and Size	2 – 150 cfs 3 – 400 cfs	2 – 150 cfs 3 – 400 cfs	2 – 150 cfs 3 – 400 cfs	2 – 150 cfs 3 - 400 cfs
Plant capacity (Total cfs)	1500 cfs	1500 cfs	1500 cfs	1500 cfs
Conduit Sizes (No. & Diameter)	2 – 8 ft 1 – 6 ft	2 – 8 ft 1 – 6 ft	2 – 8 ft 1 – 6 ft	2 – 8 ft 1 – 6 ft
Bypass Channel				
Bottom Width (ft)	40	70	30	30
Side Slopes	3:1	3:1	3:1	3:1

Chapter 3: OPERATION STUDIES

3.1 General

The purpose of the operation studies is to identify the project benefits in terms of Delta ecosystem enhancement and increased reliability of the water supplies for users of the State and the federal water projects. System-wide water supply changes that could occur as a result of additional storage in the Delta are evaluated in this chapter.

If operated as a component of the State Water Project (SWP) and/or Central Valley Project (CVP) systems, In-Delta Storage reservoirs could:

- provide water to meet Delta standards (D1641 and D1643) and should supplement flows released by the SWP and CVP to meet such standards. The project should also show viable operations under the CUWA Water Quality Management Plan settlement agreement and biological opinions. Due to its location in the Delta, the project is ideally situated to manage Delta conditions and could respond rapidly to changed conditions;
- create additional benefits for Ecosystem Restoration Program (ERP). Also, at times when exports are restricted under EWA actions, In-Delta storage could help make up for export reductions by releasing the stored water in the Delta that could be exported through Banks and Tracy Pumping Plants. The project could improve flow releases and export timing to benefit Delta fisheries and improve water quality for fish in the Delta;
- cause no impact on drinking water quality by operating these reservoirs in such a way that reservoir water quality would not degrade due to elevated levels of total organic carbon (TOC). Also, releases from storage could reduce salinity intrusion and result in water quality benefits;
- increase reliability and flexibility through additional water supply and increases in upstream carryover storage. The additional water supply should result from capturing surplus flows in the Delta. Also, water stored during excess periods and released for Delta requirements, may result in savings for projects and can end up as additional carryover in SWP and CVP reservoirs; and
- provide storage and water marketing for sale, exchange, lease or transfer of water from one user to another.

Operational studies were conducted with the California Simulation Model II (CALSIM II) and the Delta Simulation Model (DSM2). As standards in the Delta are daily standards, daily versions of these models were used. Additional information on operating criteria and use of models is presented in the following sections. Detailed information on operational analysis is available in the DWR Draft Report on Operations, December 2003.

3.2 Operational Criteria

3.2.1 Level of Development

A 2020 level of development for land use is assumed. At the start of the feasibility study, evaluations were planned to be based on a 2030 level of development. However, 2030 hydrology is currently being developed under the Common Assumptions multi-agency task, which may be completed during the next year. The present study assumed 2020 level of development for the No Action base scenario and Project conditions. Although a land use change is expected from the present to the 2020 level planning horizon, hydrological studies indicate that future 2020 level hydrology based water supply may not show appreciable change. With the increase in population, water demands are expected to change. These demands include a total annual SWP demand that varies between 3.4 MAF and 4.2 MAF. The maximum interruptible demand is 134 taf per month. The total annual CVP demand is 3.5 maf, which includes an annual Level II Refuge demand of 288 taf. The Cross Valley Canal demand is 128 taf/year, while Trinity River Minimum Fish flows below Lewiston Dam are maintained at 360 taf/year.

Currently SWP and CVP systems are being operated according to the SWRCB's Water Rights Decision 1641. The current system represents the 2001 system hydrology, water demands, facilities, D1641 regulatory standards and COA operations.

3.2.2 Operational Criteria for No Action Base Alternative

To determine operational impacts, modeling applications for the No Action future conditions Common Assumptions which represent the same operations criteria for all five storage projects are to be used for the In-Delta Storage operations. Details of the No Action Common Assumptions are given in the DWR Draft Report on Operations, December 2003. A summary of the criteria applied to the No Action Base alternative is discussed below.

3.2.2.1 Water Quality Control Plan D1641 Requirements

The diversion flow and water quality criteria set forth by the 1995 Water Quality Control Plan (1995 WQCP), D1641, are shown in Figure 3.1. The water quality plan sets the operation rules based on flow standards and water quality requirements in the Delta. Key provisions of the 1995 WQCP are as follows.

- Under flow standards, the plan specifies the upper limits on exports amounts.
- It also specifies the minimum flow requirements for water quality objectives for agriculture, municipal, industrial, fish and wildlife at key locations in the Delta and the operation schedules of the Delta Cross Channel.
- The water quality standards deal with the water quality issues at export locations, interior of the Delta and the western Delta. It also specifies the limits of water quality for salinity at San Joaquin River and Suisun Marsh.
- For the upstream reservoir operations, CVPIA instream flow operations are represented by the modeling criteria for the Department of the Interior's Final Administrative Proposal on the Management of Section 3406(b)(2) Water, November 1997.

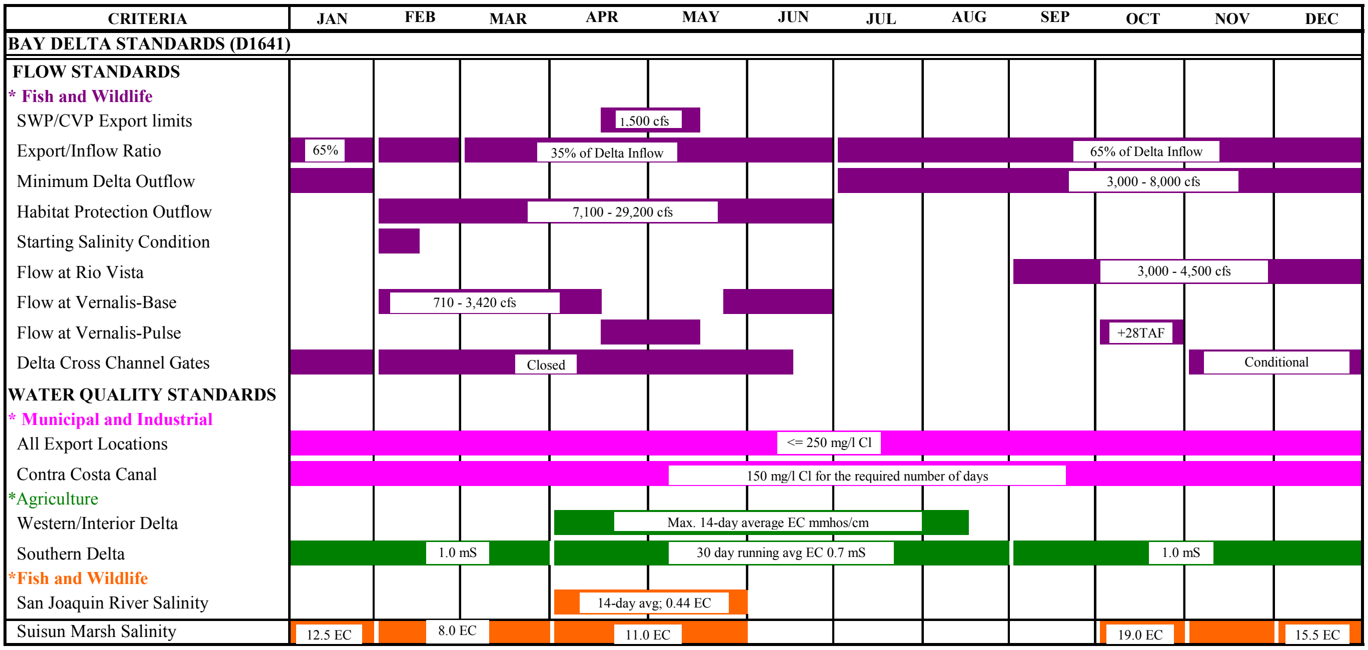


Figure 3.1: 1995 Water Quality Control Plan (D1641) Requirements

In addition to the 1995 WQCP requirements, No Action Base criteria assumes that Banks pumping capacity based on the fisheries revised preferred alternative (REV FISH), is permitted with variations of 8500 cfs for October – 15 March, 6680 cfs for 16 March – 30 June and 8000 cfs in July, August and September).

3.2.2.2 CVP/SWP Operations Under Coordinated Operations Agreement (COA)

Under the Coordinated Operations Agreement (COA), the SWP and CVP are required to assure that each project obtains its share of water from the Delta and bears its share of obligations to protect other beneficial uses in the Delta and the Sacramento Valley. The projects share water based on agreed upon percentages during balanced or excess flow conditions in the Delta. Banks Pumping Plant wheels water for the CVP when there is excess capacity at Banks Pumping Plant. The In-Delta Storage Project can assist in storing CVP storage withdrawals that are to be wheeled by Banks Pumping Plant into CVP San Luis Reservoir. COA can also help in transferring EWA water. EWA water temporarily stored in In-Delta Storage reservoirs will be transferred by Banks Pumping Plant to the EWA storage account in San Luis Reservoir.

3.2.2.3 Joint Points of Diversion

CVP/SWP operations include "joint points of diversion and use" to allow use of facilities for SWP and/or CVP operations. Before facilities are shared under the Joint Points of Diversion agreement, the project sharing its facilities must first meet its own obligations.

3.2.3 In-Delta Storage Project Operations

The In-Delta Storage Project is considered as a component of the SWP and CVP system for the purpose of these analyses. In addition to D1641, COA operations, and Joint Points of Diversion, criteria for project operations include D1643 needs/requirements (including biological opinions and CUWA Water Quality Management Plan requirements). The project operations also include CVPIA level 4 refuge supply and conjunctive groundwater and surface water use.

3.2.3.1 SWRCB Decision 1643 Requirements

The SWRCB Decision 1643 conditionally approved the Delta Wetlands Properties water right application to appropriate water by direct diversion and storage on Webb Tract and on Bacon Island. A detailed set of constraints that the project must satisfy is given in the DWR Draft Report on Operations, December 2003. Other storage projects being studied for the Bay-Delta Program have not yet progressed far enough in the process to have their own assigned operational requirements similar to D1643 for In-Delta Storage. The operation criteria of the In-Delta Storage Project, which is considered as a joint State and federal project, may change and final requirements would be established through SWRCB review of the DW Permit after the subsequent EIR/EIS process is complete. The DW permit requirements are shown in Figure 3.2 and the main provisions are summarized below. More details on these provisions are given in Appendix A of the December 2003 Draft Report on Operations.

- Allowable diversion to storage could only occur when all Delta outflow requirements are met.

- Initial diversions to the DW Project shall not be made for the current water year (commencing October 1) until salinity (X2) has been west of Chipps Island (75 km upstream of the Golden Gate Bridge) for a period of ten (10) consecutive days. There are additional restrictions on diversions during other times of the year based on X2 position.

- The maximum rate of diversion onto either Webb Tract or Bacon Island would be 4,500 cfs (9 taf/day). The combined maximum daily average rate of diversion for all islands (including diversions to habitat islands) will not exceed 9,000 cfs.

- The total amount of water taken from all sources shall not exceed 822 taf per water year (October 1 to September 30). Also, maximum annual release of stored water would be 822 taf.

- The amount of water that can be diverted depends on fisheries restrictions as well as WQMP surplus and Delta Outflow constraints.

- The maximum annual export of stored water would be 250 taf. No releases shall be made for export from Webb Tract from January through June.

- DW Project releases are subject to monthly Export/Inflow ratio constraints except when water is discharged for the environmental water account.

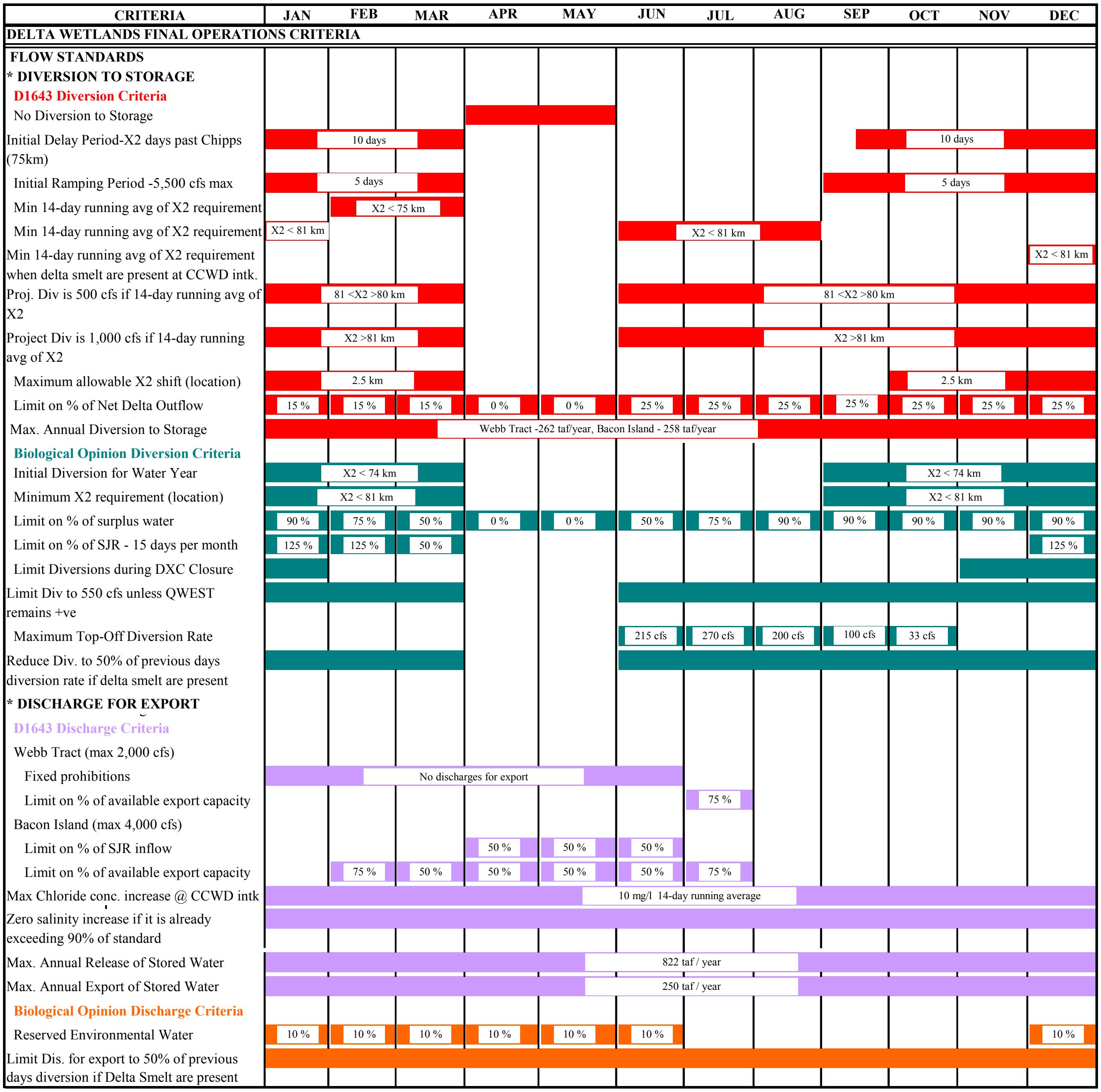


Figure 3.2: D1643 Constraints in the Delta Wetlands Properties Permit

3.2.3.2 CVPIA

In-Delta Storage could provide water for supplies (in addition to Level 2 refuge supply) to meet Level 4 refuge demand and thus releases could be made to benefit CVPIA. It would protect, restore, and enhance fish, wildlife, and associated habitats in the Central Valley with additional water supply for refuges. This CVPIA use could also be considered as system-wide use and could assist in meeting the following CVPIA objectives:

- improve the operational flexibility of the CVP; and

- achieve a reasonable balance among competing demands for use of CVP water, including the requirements of fish and wildlife, agriculture, municipal and industrial, and power contractors.

3.2.3.3 Groundwater and Surface Water Conjunctive Use

The In-Delta Storage Project could provide additional water for recharge to help control groundwater overdraft south of the Delta and also improve water supply reliability by in-lieu transfers of water for the other state-wide urban and agricultural users. Further details of conjunctive use operations are given in the December 2003 Draft Report on Operations.

3.3 Operations Modeling

3.3.1 CALSIM Model Development

The California Simulation Model (CALSIM) is a generalized water resource planning tool developed jointly by the Department of Water Resources (DWR) and the U.S. Bureau of Reclamation Mid-Pacific Region (Reclamation). CALSIM II is the application of the CALSIM software to model the State Water Project (SWP), the federal Central Valley Project (CVP) and areas tributary to the Sacramento-San Joaquin Delta (Delta). The primary purpose of the CALSIM II model is to evaluate the performance of the CVP and SWP systems: 1) at current or future levels of development, 2) with and without various assumed future facilities and, 3) with different modes of facilities operations. Comparative analysis of model results can be used to assess the water supply impacts of any proposed expansion of project facilities, changes in regulatory requirements, changes in operating criteria, or many other “what-if” scenarios.

The model was developed to simulate system operations using a monthly time step. Because SWRCB requirements and other regulations are imposed as daily standards, modeling In-Delta Storage operations required a model with a daily time-step for defining the diversion and release rules. A “Daily Delta Model” was developed for this purpose and was used in conjunction with the CALSIM monthly model for North and South of Delta operations.

An Artificial Neural Network (ANN) routine has been developed and implemented in CALSIM II to correlate DSM2 model-generated salinity at key locations in the Delta to Delta exports, Delta Cross Channel operations, and major Delta inflows. The ANN flow-salinity module predicts electrical conductivity at the following three locations: Old River at Rock Slough, San Joaquin River at Jersey Point, and Sacramento River at Emmaton.

3.3.2 Interactive CALSIM II Model Applications

The entire system’s operation was simulated for one month with the CALSIM II monthly model and then Delta inflows and south-of Delta delivery amounts were passed on to the Daily Delta Model. The Daily Delta Model then re-simulated Delta and export facility operations for the same month.

Average monthly Delta inflows from the monthly model were converted into daily hydrographs. For this purpose, a utility program was developed to pattern the average monthly Delta inflows after the historically recorded flows. Historic flows of the Sacramento River at Freeport, the San Joaquin River at Vernalis, a combination of the Mokelumne River at Woodbridge and the Cosumnes River at Sloughhouse, and a combination of flows at the gage near Woodland, the Sacramento Weir near Bryte, and Putah Creek near Davis were analyzed.

After the Daily Delta Model simulated one month's operation, the results were provided to the monthly model as the initial conditions for the following month's simulation. Operation of the upstream reservoirs was not re-simulated, and any gains or losses of water were reflected in Delta outflow and San Luis Reservoir storage results. The next month's simulation was then started with the modified end-of-month storage in San Luis Reservoir and the state of the Delta as simulated by the Daily Delta Model. This month by month process was repeated for the entire simulation period.

Interaction between the CALSIM II daily model, DSM2 and DYRESM models was required to evaluate impacts on drinking water quality constituents including organic carbon. CALSIM II output was used in DYRESM to perform reservoir stratification studies. The delivery information from the CALSIM model was used as input in the economic models to determine economic benefits of the project as presented in Chapter 7.

3.4 Operations Scenarios

The operational scenarios developed for this feasibility study are samples of how the In-Delta Storage Project could be operated; however, many operational scenarios are possible. Some of the scenarios are designed to address the most pertinent single objective while others combine multiple sets of objectives such as water supply reliability, EWA and ERP Delta flows.

The No-Action Base is considered as without project Scenario 1. Three sample scenarios with In-Delta Project operations are:

- **Sample Scenario 2** shows one operational scenario with an emphasis on water supply.
- **Sample Scenario 3** shows one operational scenario with an emphasis on water supply and the EWA.
- **Sample Scenario 4** shows one operational scenario with an emphasis on water supply, EWA, and ERP Delta flows.

Six subsequent impact evaluation studies were developed based on Scenario 4 as this scenario included all three evaluations (water supply, EWA and ERP). These studies were designed to analyze the impacts of applying DOC constraints, dilution of DOC through circulation, fisheries most restrictive, climate change, and coordinated operation with expanded Los Vaqueros Reservoir, and SWRCB D1643. The six impact studies are:

- Study 4a: Initial Project Conditions w/ DOC Constraints Applied
  (Study 4 with DOC Constraints)
- Study 4b: DOC Dilution through Circulation
  (Study 4 with DOC Constraints and Circulation)

- Study 4c: Fish and Aquatic Habitat Protections during Drought and Most restrictive
  (Study 4 with Fall Midwater Trawl Abundance Index, FMWT <239)
- Study 4d: Climate Change Impact
  (Study 4 with updated hydrology)
- Study 4e: Coordination with Los Vaqueros Expanded Reservoir
  (Study 4 with LV Operation)
- Study 4f: Impact of D1643 on In-Delta Storage Operations
  (Study 4 without D1643)

3.4.1 Study 1: No Action Base Operations

The No Action base case study simulates the existing facilities of the system for a 2020 level of hydrology and demands without the In-Delta Storage Project facilities in the system. In the No Action Base study, all the rules specified in the D1641 water quality requirements already stated in Section 3.2.2.1 will be used. In addition, 8500 cfs expanded capacity at Banks Pumping Plant will be used as required under the fisheries preferred alternative (8500 cfs October – 15 March, 6680 cfs 16 March – 30 June and 8000 cfs in July, August and September). This study also includes coordinated SWP/CVP operations under COA and joint points of diversion wheeling for the CVP through Banks Pumping Plant.

Study assumptions for the No-Action Base and three operational scenarios are given in Appendix B and study specifications are given in Appendix C, December 2003 Draft Report on Operations. The supplies computed for all "with project" scenarios will be relative to the No-Action Base. Results of the No-Action Base study for the 73-year period are given in Table 3.1.

3.4.2 In-Delta Operations

All three operational scenarios include the following:

- Coordinated operations of the In-Delta Storage Project with SWP/CVP operations under SWRCB May 1995 WQCP Water Right Decision 1641, Water Right Decision 1643, CUWA Water Quality Management Plan (with the exception of Organic Carbon constraints), and Biological Opinions (with the exception of FMWT less than 239);
- CVPIA level 4 refuge demands in addition to level 2 refuges; and
- Groundwater surface water conjunctive use.

Studies 2, 3, and 4 do not include the DOC, salinity, DO and temperature constraints specified in D1643 and the Water Quality Management Plan. However, the DOC issue is addressed in the impact evaluation studies 4a and 4b. As no specific releases were made for improvements to salinity, DO and temperature and emphasis of water quality studies was on meeting D1643 and WQMP standards, DSM2 was used to evaluate if changes in these parameters were within the specified standards. Detailed information on DSM2 applications is given in Chapter 4 on Water Quality Investigations.

The operation scenarios were evaluated and compared with the No Action Base conditions to assess benefit provided by the In-Delta Storage Project when operated in coordination with the SWP/CVP system as presented in Table 3.1.

3.4.2.1 Study 2: Water Supply Study

The objective of Study 2 is for the In-Delta Storage Project to help meet the future demands of CVP/SWP water contractors when supplies are short. The project could produce additional water deliveries to urban and agricultural water users (modeled as SWP/CVP, but could be any urban or agricultural water user). SWP and CVP allocated deliveries as of May 1 were given the first priority to be met by direct supplies to SWP and CVP users as in the Base study. The additional refuge supply and conjunctive use supply were made available only when export capacity was available. The estimated annual water supply benefits vary from 61.3 taf during the dry period (assumed as average of 1928-34, 76-77 and 87-92 dry periods), to 123.9 taf long-term average (73 year average from 1922-94).

3.4.2.2 Study 3: Water Supply Study with EWA

The objective of Study 3 is twofold: to help meet the future demands of CVP/SWP water contractors and to provide operational flexibility for the Environmental Water Account (EWA). Study 3 builds upon Study 2 by adding EWA as another buyer of In-Delta water. The EWA gives fishery agencies and state water managers increased flexibility to alter pumping and delivery schedules to protect fish without affecting water supply reliability.

In this study, no EWA actions (cuts in exports) are modeled. It is assumed the EWA takes fish protection actions, and, therefore, the EWA will have demand for In-Delta water when it and Banks export capacity are available. EWA buys the water to pay the projects back for the assumed fish protection actions. It was assumed that any water that was not needed by SWP and CVP as of May 1 could be purchased for EWA. EWA is given a lower priority to the water than the refuges and groundwater conjunctive use, but from July through September Banks permitted capacity is increased from 8000 cfs to 8500 cfs with the extra 500 cfs dedicated to moving In-Delta water for the EWA. This guarantees that, while low in priority, the EWA can purchase a significant share of the unwanted In-Delta water because it can move water that the refuges and groundwater recharge are otherwise unable to. The 500 cfs increase in permitted capacity for EWA use is part of the proposed Revised Fish Alternative of the South Delta Improvement Program.

As shown in Table 3.1, direct SWP/CVP deliveries decrease from 124 taf to 98 taf as EWA uses 31 taf of In-Delta Storage water. Total annual supply benefit is 129 taf.

3.4.2.3 Study 4: Water Supply Study with EWA and ERP

The objective of Study 4 is threefold: to help meet the future demands of CVP/SWP water contractors, to provide operational flexibility for the Environmental Water Account (EWA), and to provide additional water to help meet the Ecosystem Restoration Program (ERP) goals.

An Environmental Restoration Program (ERP) demand for increased Delta outflow in March, April and May is added to Study 3 to create Study 4. In this scenario, the ERP Delta outflow targets are 20,000, 30,000 and 40,000 cfs for an additional 10 days in March and 10 days in April/May for Dry, Below Normal and Above Normal water year types, respectively. The water year types are based on the Sacramento Valley Water Year Hydrologic Classification. The order of priority given is; SWP, CVP, refuge, groundwater conjunctive use, EWA, and ERP demand for In-Delta water.

The ERP was established to accomplish strategic program goals through habitat creation and management and the EWA was created to reach these goals through flow manipulations. Some of the implementing agencies for the EWA (USFWS, NOAA Fisheries and CDFG) are also the ERP implementing agencies. These agencies are responsible for exercising biological judgment to determine SWP/CVP operational changes to protect and enhance at-risk fish species dependent on the Delta. All of the at-risk fish species that are targeted for enhancement and recovery by the EWA are also targeted for recovery by the ERP, so there is a direct linkage between the goals of these two programs. As shown in Table 3.1, total annual supply change is 136 taf with 83 taf going to projects, 37 for EWA use and 16 taf for additional ERP Delta flow.

3.5 Impact Evaluation Studies

The impact evaluation studies were designed to compare the trade-offs that are possible when specific water management actions are applied to the In-Delta Storage Project. The remaining studies are all iterations of Study 4 (water supply, EWA and ERP) with various changes to gage the potential impact of operational constraints and modeling assumptions that were not addressed in Studies 2, 3, and 4. These include the D1643 DOC standards, fish protections in most restrictive (FMWT < 239), climate change, and changes in infrastructure such as an expanded Los Vaqueros Reservoir and increase Contra Costa export capacity. Also, the impacts of D1643 on the island reservoirs' ability to divert and deliver water were evaluated by running an In-Delta storage operation unencumbered by this decision.

Details on study specifications for these studies are given in Appendix C of the December 2003 Draft Report on operations.

3.5.1 Study 4a: Initial Project Conditions with DOC Constraints Applied

The objective of Study 4a is to model the In-Delta Storage Project with dissolved organic carbon (DOC) constraints applied, as specified in the WQMP. Study 4a builds upon Study 4 by adding DOC constraints to the In-Delta Storage Project to determine the impact on In-Delta Storage Project yield. For more details on the implementation of the constraints, see Appendix C of the December 2003, Draft Report on Operations.

When added to the CVP/SWP systems, the In-Delta Storage Project will affect water quality in the Delta. The DOC of the water channel sources (Sacramento River and San Joaquin River) coming into the reservoir is known from historical field measurements. When water is stored over peat soils, DOC growth occurs as indicated by field investigations and laboratory experiments. DOC is an important water quality issue to be resolved for project operations.

As constraints dictated by D1643 are to be applied, base water quality conditions are needed. The DOC data generated by DSM2 using Study 1 (Base) operational input covers the period from October 1975 to September 1991. To generate a 73-year data set of DOC concentrations, the 16 year DSM2 data was sorted by water year type (Sacramento Valley Water Year Hydrologic Classification) and daily averages for each location were computed. These daily average DOC time series were then applied to the remainder of the 73-years based on water year type.
As given in Table 3.2, average annual impact of DOC constraints on project yield is 20 taf in comparison to Study 4.

3.5.2 Study 4b: DOC Dilution through Circulation

The objective of Study 4b is to determine water circulation needs so that island reservoirs can be operated within the required DOC standards without impacting project yield. Study 4b is similar to Study 4a; however, an amount of up to 500 cfs will be circulated between each reservoir and the adjacent sloughs whenever favorable conditions exist between the reservoir and slough. The amount of circulation is controlled by the following criteria:

- Releases from In-Delta Storage reservoirs shall cease if they cause total organic carbon (TOC) concentrations at the urban intakes (SWP, CVP and CCWD pumping plants), and at a receiving water treatment plant, to exceed 4.0 mg/L. Storage releases or circulation may resume once the DOC concentration is below the set standard.

- Releases from In-Delta Storage reservoirs shall cease if they cause total organic carbon (TOC) concentrations at the urban intakes (SWP, CVP and CCWD pumping plants) to increase by more than 1.0 mg/L. TOC concentrations shall be calculated as a 14-day average. Storage releases or circulation may resume once the 14-day average DOC concentration is below the set standard.

With circulation, Delta water with lower DOC concentrations is passed through the reservoirs with no net change in storage. The lower DOC Delta water mixes with the higher DOC reservoir water, reducing DOC concentrations. Project diversions and discharges results from this CALSIM study were used as input to DSM2 study to determine changes to TOC values at the urban intakes and information is presented in Chapter 4 on Water Quality. As given in Table 3.2, circulation will reduce the DOC constraints annual impact by 10 taf for up to 500 cfs circulation.

3.5.3 Study 4c: Fish and Aquatic Habitat Protections during Drought and Most restrictive

The objective of Study 4c is to determine the amount of water needed to meet requirements when the Fall Midwater Trawl Abundance Index for delta smelt (FMWT) is less than 239. The FMWT Index is an indicator for determining the abundance of delta smelt within the Delta and a FMWT Index of less than 239 indicates a significant decline in delta smelt abundance.

The following procedure was used to determine the water supply impact when the FMWT Index is less than 239 during drought or extreme dry conditions:

- Study 4 was run assuming a FMWT Index of less than 239 in all 73 years. According to the constraints imposed by D1643, no diversions for storage will be made from February 15 through June 30 if FMWT is less than 239. This will negatively impact project yield.
- Assume that the FMWT Index is less than 239 during 28-percent of the 73-year study period (FMWT Index was less than 239 in 8 of 28 years from 1967 to 1994, which is 28 percent). Assume that the FMWT Index is greater than 239 during the remaining 72-percent of the 73-year study period.
- Assume the FMWT index is independent of hydrology and operations and use the formula below to calculate a weighted project yield for Study 4c.

$$\Pr ojectYield_{Study4c} = \left[\left(\Pr ojectYield_{\substack{Study4 \\ FMWT>239}} \times 0.72 \right) + \left(\Pr ojectYield_{\substack{Study4 \\ FMWT<239}} \times 0.28 \right) \right]$$

The weighted project yield (Table 3.2) with FMWT impact is 20 taf less due to the assumption that most restrictive constraint has to be met. The assumption that the FMWT index is independent of hydrology is likely conservative. If, as the Department of Fish and Game suggests, there is a positive correlation between the FMWT index being less than 239 and drought conditions, the negative impact of the FMWT index conditional constraints in D1643 will be less than reported. Due to other constraints on island operations, IDS rarely diverts water during drought conditions which is at the same time that the FMWT is most likely to be low. Obviously, zero diversions can not be decreased.

3.5.4 Study 4d: Climate Change Impact

The objective of Study 4d is to assess the impacts climate change may have on the In-Delta Storage Project yield. Because of the project's location, In-Delta Storage would capture early spring flows and store additional water that may end up in the Bay. Study 4d uses a different hydrology than study 4. The hydrology used in Study 4d is modified to reflect changes in the climate in the region due to global warming. To accurately compare the results of this study, a modified No-Action Base study (Study 1d) that uses the same modified hydrology as Study 4d was created by shifting inflows into the Delta from spring (March, April or May flows) to winter flows (January or February. Results of this scenario are compared with No Action Base (Study 1) and are shown in Table 3.2. The results indicate that the project yield will marginally change over time. For example, this study shows an average annual delivery of 139 taf in comparison to 136 taf for Study 4 without climate change. Also, there would be additional 11 taf of carryover storage in Oroville Reservoir.

3.5.5 Study 4e: Coordination with Los Vaqueros Expanded Reservoir

Purpose of this study is to assess if there are additional benefits of considering In-Delta operations in coordination with Los Vaqueros expansion. In addition, it was also the intent to see if this project is competing for the same surplus water. This project is at different level of development study. The studies are very preliminary and no final operational plans have been developed. Focus of this study was on trend evaluation rather than importance of numbers. The current operational studies for operating expanded Los Vaqueros are appraisal level scenarios based on D1641 requirements with

2020 hydrology based on a monthly time step, whereas In-Delta has additional D1643 constraints and CALSIM II modeling application is on daily basis.

Diversion information for the Los Vaqueros expanded reservoir was obtained from the ongoing planning studies. Los Vaqueros diversions assume a secondary use of the project after leaving a surplus flow buffer of 5,000 to 10,000 cfs that can be used by expanded Banks 8,500 cfs and future extensions in the SWP and CVP system like In-Delta storage. Results of this scenario are presented in Table 3.2. The study results indicate that the Los Vaqueros expansion will have minimal impact on In-Delta storage operations.

3.5.6 Study 4f: Impact of D1643 on In-Delta Storage Operations

Study 4f was run to determine the impact of D1643 on potential In-Delta project yield. Studies 4, 4a, 4b, and 4c were run with different combinations of D1643 constraints. Therefore, Study 4f was run without D1643 constraints for the purposes of comparison. Two constraints were retained though:

1. No island diversions during April and May.
2. Islands can only divert a percentage of available surplus water as specified in D1643 (90% Aug-Jan; 50% Mar and Jun; 75% Feb and Jul; 0% Apr and May).

In fact, this study simulates the In-Delta operations in coordination with SWP and CVP operations including Joint Points of Diversion for the period of WY 1922 – WY1994 using requirements close to D1641. Other storage projects being studied for the Bay-Delta Program have not yet progressed far enough in the process to have their own assigned operational requirements similar to D1643 for In-Delta Storage. This study would also serve as a comparison with other storage projects. Results given in Table 3.2 indicate that impact of D1643 requirements on In-Delta storage water balance is in the order of about 100 taf.

Table 3.1: Summary of Results for Sample Operational Scenarios

CALSIM-II Study No. Study Period Oct 1922-Sept 1994	Island Diversion (TAF)	Island Discharge (TAF)	Contribution to D1641 (TAF)	SWP/CVP Delivery (TAF)	Change in Water Supply (TAF)				Change in Oroville Carryover Storage (TAF)	In-Delta Storage Project Carryover Storage (TAF)
					SWP/CVP Delivery	EWA	ERP	Total Water Supply Change		
Study 1: No Action Base Case (D1641)	-	-	-	5774	-	-	-	-	2028	-
Study 2: Water Supply (Project with D1641 & D1643)	159	159	19	5898	124	-	-	124	+35	31
Study 3: Water Supply / EWA (D1641 /.D1643 and EWA)	165	165	19	5872	98	31	-	129	+36	11
Study 4: Water Supply / EWA / ERP (D1641 / D1643, EWA and ERP)	165	165	15	5857	83	37	16	136	+22	11

Table 3.2: Summary of Results for Impact Evaluation Scenarios

CALSIM-II Study No. Period Oct 1922-Sept 1994	Island Diversion (TAF)	Island Discharge (TAF)	Contribution to D1641 (TAF)	SWP/CVP Delivery (TAF)	Change in Water Supply (TAF)				Change in Oroville Carryover Storage (TAF)	In-Delta Storage Project Carryover Storage (TAF)
					SWP/ CVP Delivery	EWA	ERP	Total Water Supply Change		
Study 1: No Action Base Case (D1641)	-	-	-	5774	-	-	-	-	2028	-
Study 4: Water Supply / EWA / ERP (D1641 / D1643, EWA and ERP)	165	165	15	5857	83	37	16	136	+22	11
Study 4a: Initial Project Conditions with DOC Constraints Applied (Study 4 with DOC Constraints)	145	145	10	5861	87	15	14	116	+4	55
Study 4b_200: DOC Resolution through Circulation (Study 4 with DOC Constraints and 200cfs maximum Circulation)	147	147	12	5863	89	18	15	122	+9	45
Study 4b_500: DOC Dilution through Circulation (Study 4 with DOC Constraints and 500cfs maximum Circulation)	153	153	13	5866	92	20	14	126	+17	38
Study 4c: Fish and Aquatic Habitat Protections during Drought and Most restrictive (Study 4 with FMWT < 239)	143	143	13	5844	70	31	15	116	0	10
Study 1d: Base for Climate Change Impact Study (D1641 with updated hydrology)	-	-	-	5740	-	-	-	-	1790	-
Study 4d: Climate Change Impact (Study 4 with updated hydrology. Compared with Base Study 1d)	163	163	15	5832	92	33	14	139	+33	11
Study 4e: Coordination with Los Vaqueros Expanded Reservoir (Study 4 with expanded LV operation)	159	159	14	5853	79	36	14	129	+14	11
Study 4f: Impact of D1643 on In-Delta Storage Operations (Study 4 without D1643)	270	270	26	5896	122	44	14	180	+50	50

3.6 Regional and System-wide Evaluations

This section discusses potential system-wide impacts of In-Delta Storage for the three sample operational scenarios and also includes impact evaluations by changing operation conditions as required by various regulations. Many factors can affect the operation of the In-Delta Storage Project, but it is difficult to assess the combined impacts of multiple conditions at the same time. The In-Delta Storage Project could cause changes to water supply reliability, system operational flexibility, additional carryover storage, Environmental Water Account assets, Ecosystem Restoration Program flows, in-lieu recharge for groundwater for transfer of water for urban and agricultural State-wide demands and Delta water quality. More details on operational evaluations are presented in Chapter 5 of December 2003 Draft Report on Operations. Brief descriptions given here show how typical In-Delta Storage operations impact the State-wide system.

3.6.1 Water Supplies Reliability

Regional and system-wide contributions of In-Delta Storage are related to increase in exports, supply for Delta requirements, EWA, ERP Delta outflows and changes in carryover storage in San Luis and upper SWP and CVP reservoirs. As shown in Figure 3.3, the system reliability probability analysis indicates increased reliability at all times.

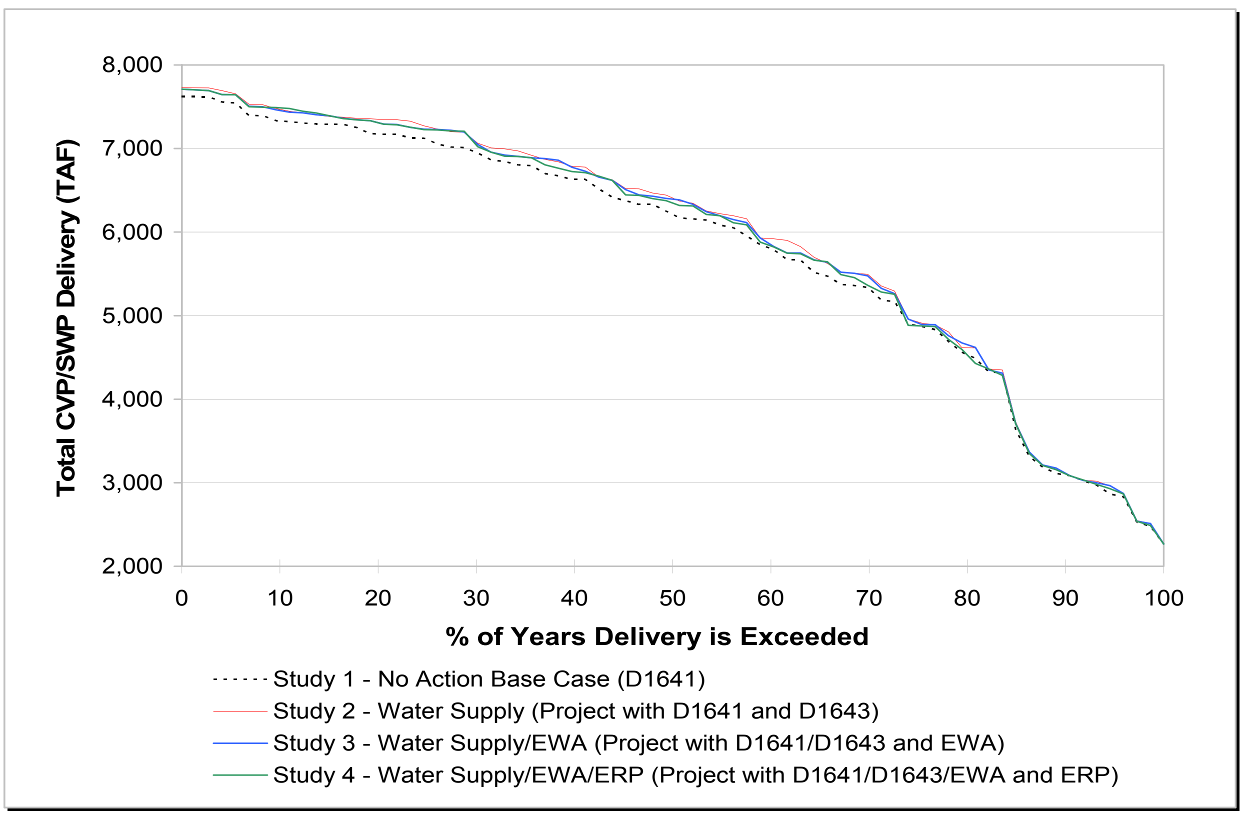


Figure 3.3: Water Supply Reliability

The system-wide impacts extend not only to South of the Delta but are also realized in the North. An increase in CVPIA refuge water in addition to the agricultural and urban supplies results from surplus water being captured by additional storage in the system. Also, as SWP and CVP obligations are met by new storage and additional carryover storage becomes available for system reliability. Long-term average annual quantifiable water supply changes for variations to Study 4 not including the changes in carryover storage are shown in Figure 3.4.

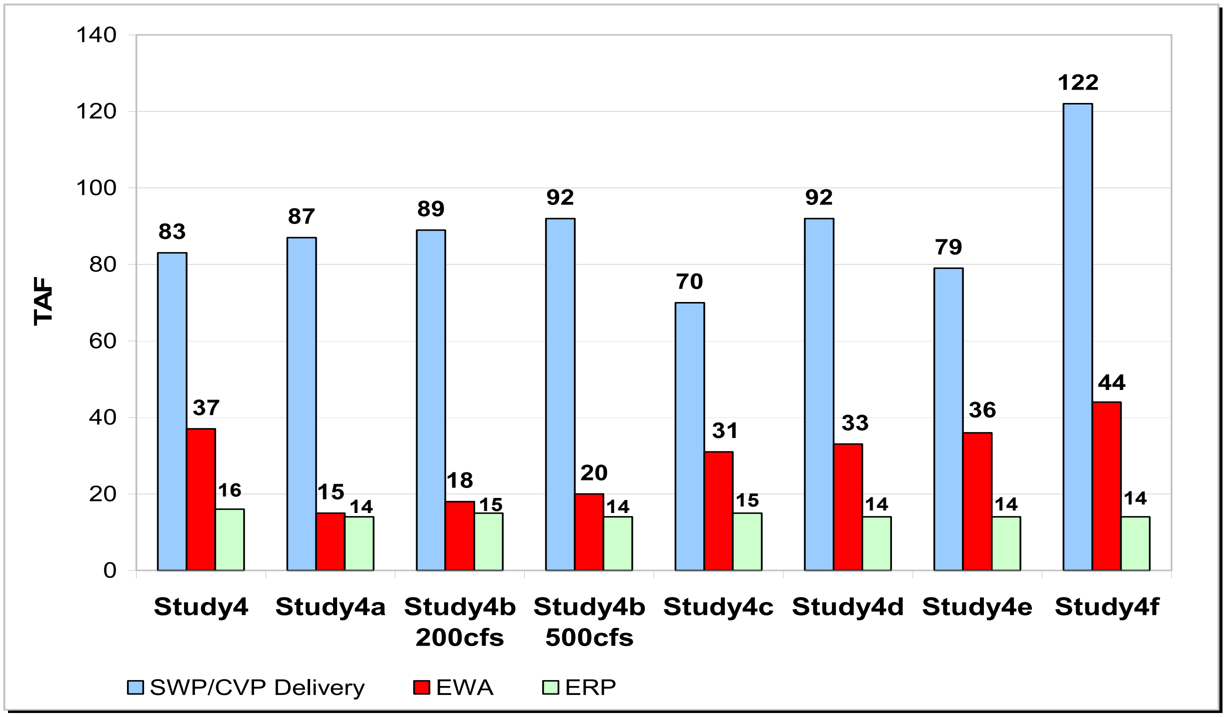


Figure 3.4: Long-Term Average Annual Change in Water Supply

3.6.2 SWP and CVP System Operational Flexibility

The In-Delta Storage Project would improve the operational flexibility of the CVP and SWP. The project's strategic location within the Delta provides enhanced flexibility in responding to short-term operational needs resulting in greater environmental protection and water supply reliability.

Due to its strategic location in the Delta, In-Delta Storage can respond quickly to accommodate real time operational needs. The In-Delta Storage Project provides a significant amount of water that could be used on short notice for export through the south Delta pumps, or release for real time Delta outflow, water quality and fisheries flows. This gives the water system unique operational flexibility that cannot be supplied by upstream storage that requires greater travel times for released water to reach the Delta.

The measure of flexibility could not be translated to a quantifiable value in terms of water supply change or monetary value. However, it is obvious that the In-Delta Storage Project adds considerable operational flexibility for aquatic resources, water quality, Delta requirements and water supply operations.

3.6.3 Carryover Storage

The system-wide benefits of In-Delta Storage extend not only to south of the Delta but are also realized upstream. A portion of SWP and CVP obligations are met by In-Delta Storage and as a result of In-Delta Storage operations, upstream carryover storage becomes available for other potential system-wide uses such as benefiting the cold water pool, recreation and improving the reliability of other project deliveries. A large part of this additional carryover storage occurs in Lake Oroville, as shown in Figure 3.5. It should be noted, however, that the potential uses of this additional carryover storage were not modeled. If the potential uses are modeled, negative impacts to other water users should be avoided.

Uses of this storage can be optimized through further operational studies in coordination with upstream reservoirs. Operations can be refined by:

- flow augmentation in the Sacramento River,
- moving water during fall months to In-Delta Storage for Delta ecosystem ,EWA and ERP use, and
- using water for temperature control and other water quality benefits.

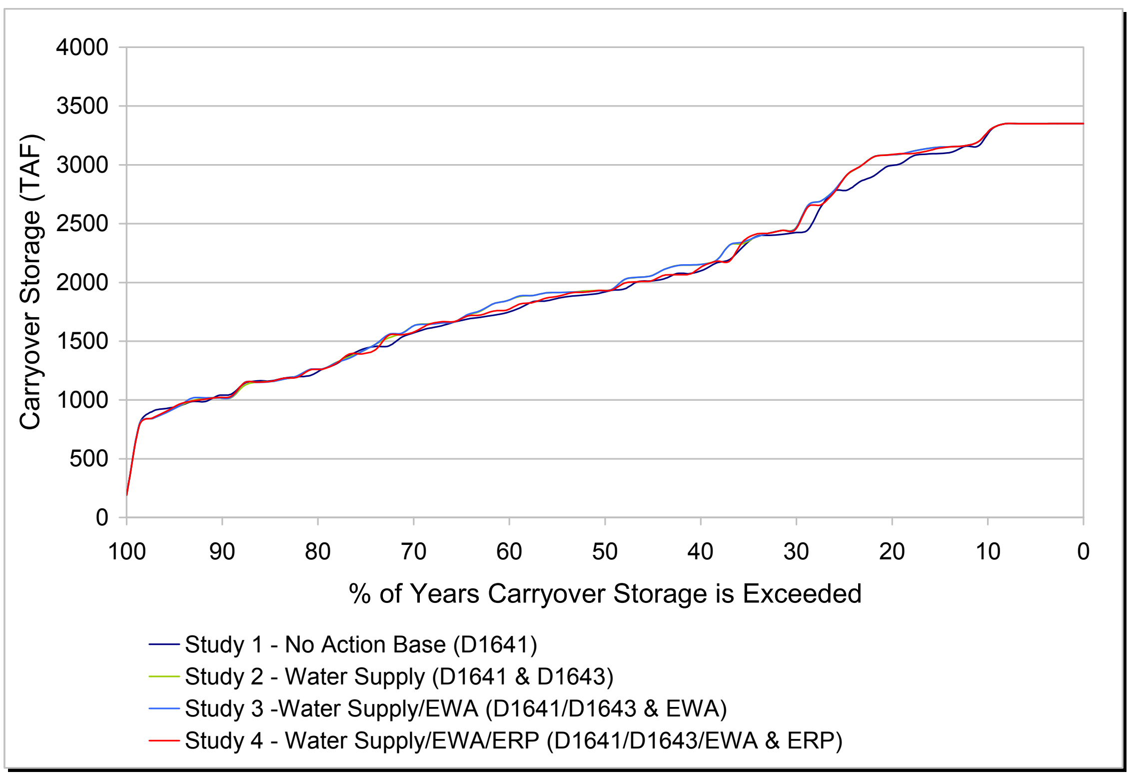


Figure 3.5: Long-Term Oroville Carryover Storage

3.6.4 Environmental Water Account

In-Delta Storage could provide water needed to support the EWA program, enhancing the EWA ability to respond to real-time fisheries needs and eliminating the need to purchase a substantial portion of water, from other sources, needed by EWA each year. EWA can purchase a significant share of the unwanted In-Delta Storage water because it can move water that the refuges and groundwater recharge are otherwise unable to.

Figure 3.6 shows the annual exceedance frequency of reservoir island releases for EWA compared to releases for SWP/CVP deliveries under Studies 3 and 4. This exceedance curve represents the likelihood that releases of a specific amount will be met or exceeded. For example, total releases for EWA under Study 4 are at least 40 TAF/year in 30% of the years. The total releases made are the summation of releases made for SWP/CVP deliveries and those made for EWA.

Figure 3.6: In-Delta Storage Supply Contribution to EWA

3.6.5 Ecosystem Restoration Program

The In-Delta Storage Project can provide water for ecosystem restoration actions to help restore and improve the health of the Bay-Delta system for all native species while reducing its water management constraints. This project can help maintain flow regimes in the Delta that support the recovery and restoration of native aquatic and riparian species and biotic communities. Figure 3.7

shows the annual exceedance frequency of reservoir island releases for ERP Delta flows compared to releases for SWP/CVP deliveries under Study 4. The island releases shown in this figure are additive. In other words, the total releases made are the summation of releases made for SWP/CVP deliveries and those made for ERP.

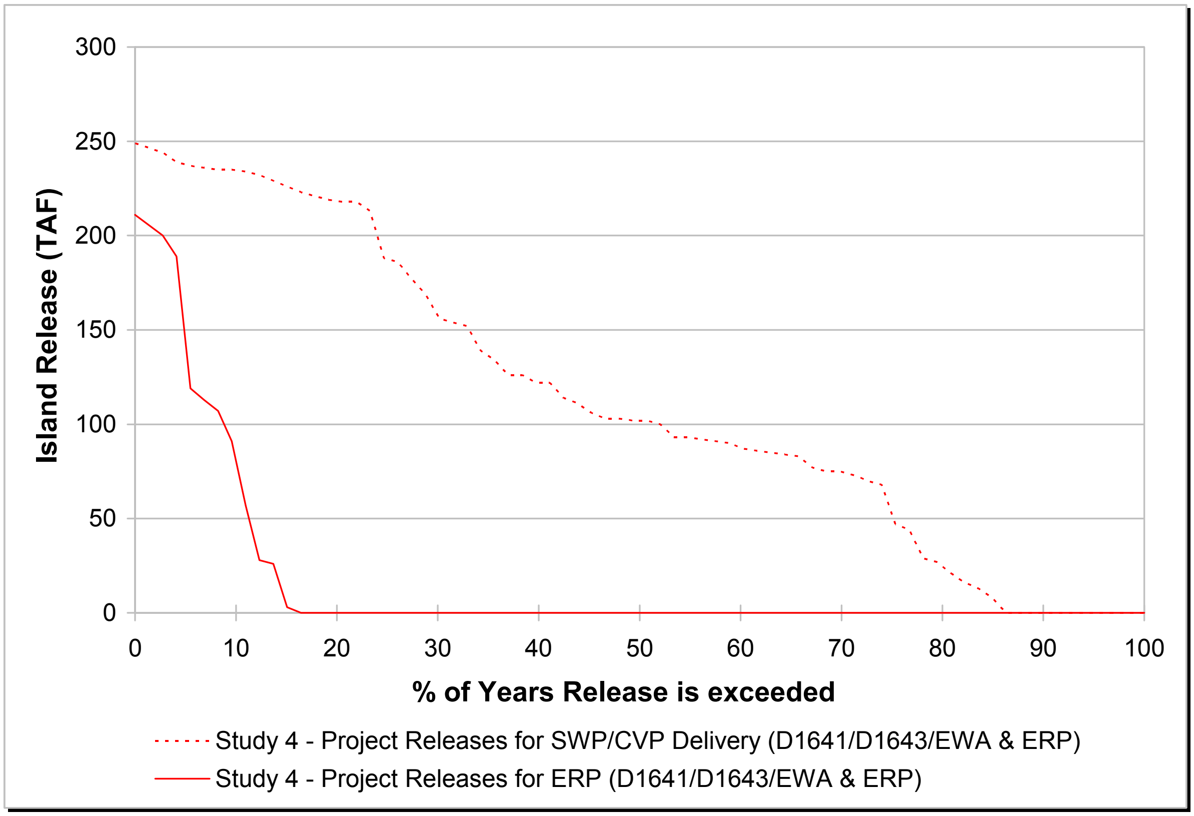


Figure 3.7: Dedicated In-Delta Storage Supply Contribution to ERP

3.6.6 Water Quality

3.6.6.1 Salinity

The location of the 2 ppt salinity isohaline (X2 location) has been identified as an important indicator of estuarine habitat conditions within the Bay-Delta system. The location of X2 within Suisun Bay during the February to June period is thought to be directly and/or indirectly related to the reproductive success and survival of the early life stages for a number of estuarine species. Abundance of several estuarine species is greater when the X2 location during the spring occurs within the western portion of Suisun Bay with lower abundance correlated with those years when the X2 location is further to the east.

The In-Delta Storage Project has the potential to improve water quality in the Delta. Due to its strategic location, higher quality water released from the project may reduce salinity in the Delta when Delta water quality is poor. None of the operational studies conducted for this feasibility study emphasized improving water quality. Further studies emphasizing water quality improvements should be conducted to determine the extent to which In-Delta Storage can improve Delta water quality. Salinity changes are evaluated by DSM2 to determine if the CALSIM results are within the variations allowed by D1643. The CALSIM results indicate that the project's impact to X2 position and salinity are negligible. DSM2 evaluations are given in Chapter 4 on Water Quality Investigations.

3.6.6.2 Organic Carbon Evaluations

Study 4a was run to obtain the initial project conditions with organic constraints applied. The total impact to water supply when organic carbon constraints are applied is only about 20 taf/year on average. Circulating water onto and off of the reservoir islands can improve water quality (by reducing organic carbon) in the reservoirs, thereby reducing the total impact to water supply. Study 4b included two circulation runs, one at 200 cfs and another at 500 cfs. Sensitivity analyses showed that circulating more than 500 cfs does not further reduce organic carbon concentrations on the reservoir islands.

As an example, typical reservoir operations for a below normal year, such as 1979, which followed the historically severe drought of 1976-77, are shown for Bacon Island in Figure 3.8 and for Webb Tract in Figure 3.9. Tidal levels and reservoir stages allow water to be diverted by gravity, gravity and pumping, and pumping only operations.

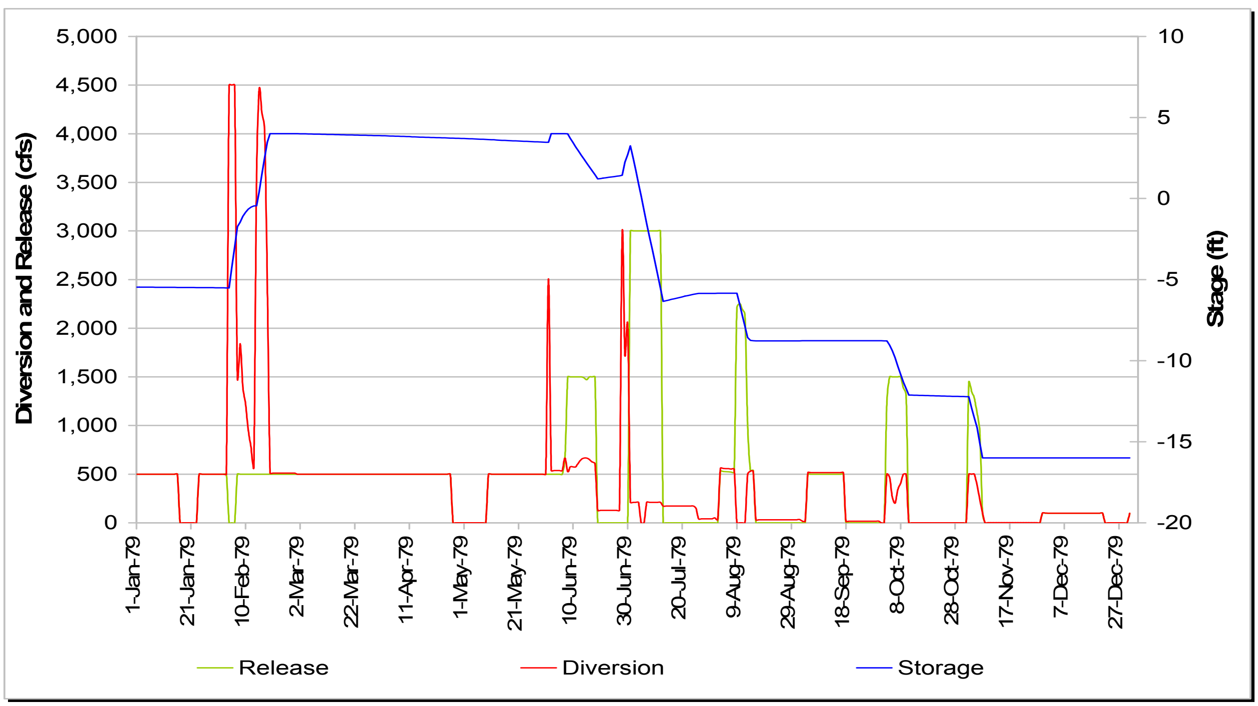


Figure 3.8: Bacon Island Operations in Below Normal Year - Study 4b

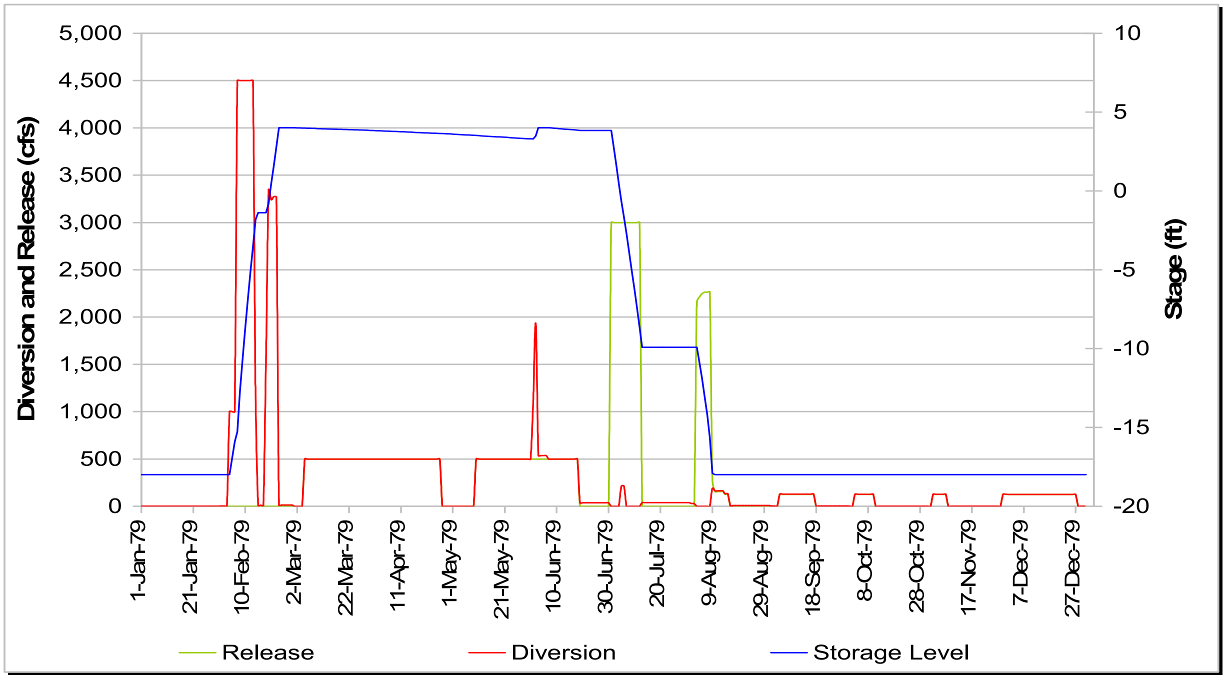


Figure 3.9: Webb Tract Operations in Below Normal Year - Study 4b

Figures 3.10 and 3.11 show long-term average diversions to reservoir islands for storage and for circulation. Circulation water is not stored and is diverted and is released through out the day as long as releases do not cause exceedance of the TOC standards at the urban intakes.

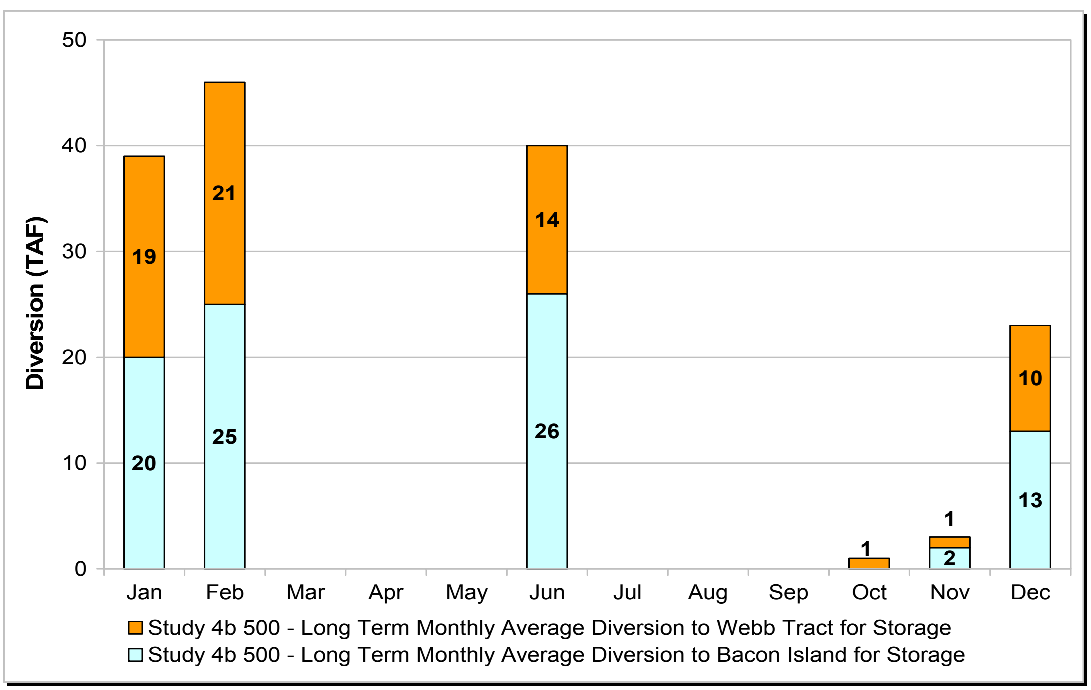


Figure 3.10: Long-Term Monthly Average Diversions for Storage – Study 4b

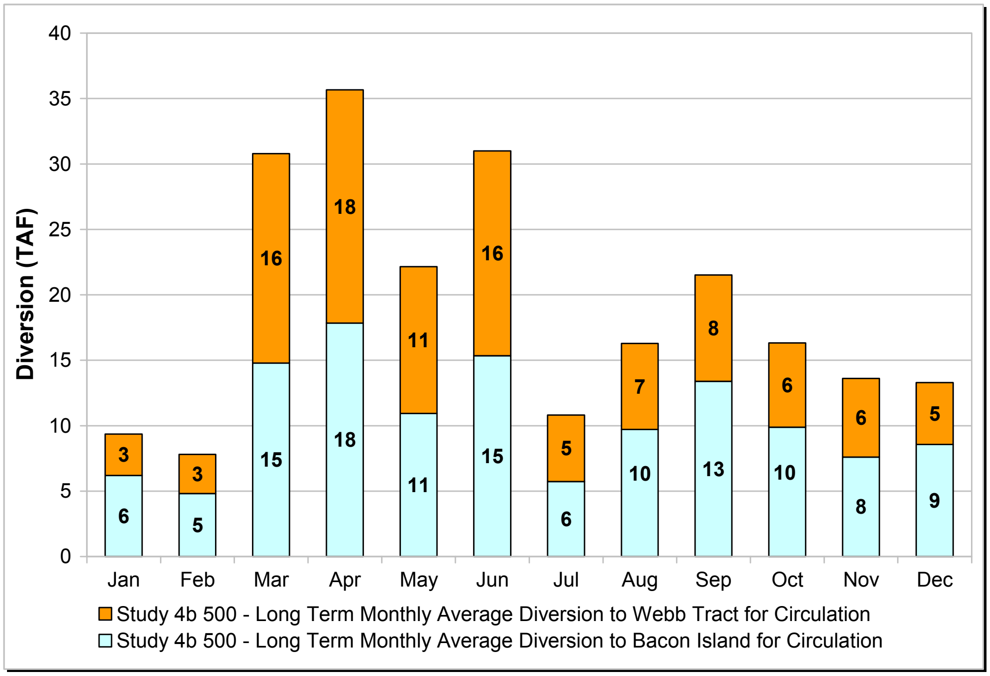


Figure 3.11: Long-Term Monthly Average Diversions for Circulation – Study 4b

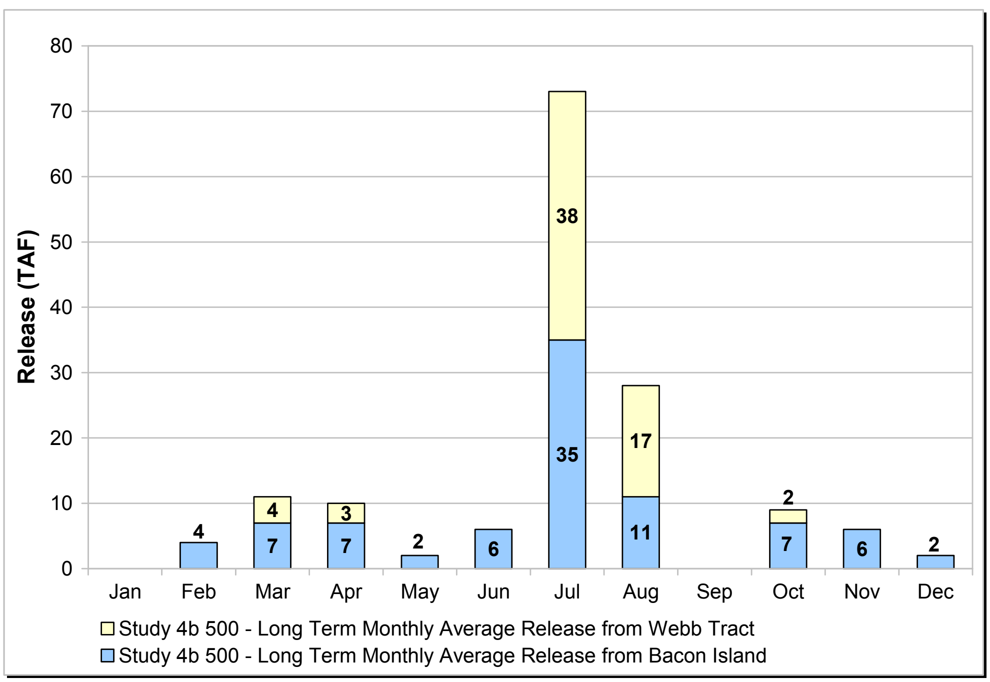


Figure 3.12: Long-Term Monthly Average Operational Releases from IDS – Study 4b

As shown in Figure 3.12, long-term average releases from reservoirs for water supply operations for a circulation type study occur mostly through out the year. The results indicate that In-Delta Storage operations, both with and without circulation, stay within the required DOC standards at the export locations from January through June of typical wet and below normal years. From June through December of typical wet, below normal and dry years, the DOC standards are periodically exceeded. Without circulation, the standards are exceeded by up to 1.5 mg/l at Banks, 1 mg/l at Tracy and 2 mg/l at Contra Costa in typical wet and below normal years and by up to 3 mg/l at Banks, 2 mg/l at Tracy and 2 mg/l at Contra Costa in typical dry years.

Circulation operations significantly reduce the amount of DOC coming off the reservoir islands, reducing the overall DOC impact at the export locations. With circulation operations, the standards are found to be exceeded by only up to a maximum of 1 mg/l at Banks, 0.5 mg/l at Tracy and 1 mg/l at Contra Costa in typical wet and below normal years and are rarely exceeded by no more than 0.5 mg/l in typical dry years. As a result of this, the overall water supply impact of operating under the required standards is reduced by up to 10 taf/year on average.

These results indicate that circulation can work as a tool to help resolve potential DOC problems encountered by In-Delta Storage operations. There may be additional ways to operate in a way to further reduce DOC impacts, but this method shows that the issue can be resolved. Further operational studies can be conducted to refine In-Delta Storage operations.

3.6.7 Assessment of Fish and Aquatic Habitat Protections

The In-Delta Storage project's location is unique and allows swift action to be taken to respond to instream flow requirements for fish and aquatic habitat. Seasonal timing and magnitude of water diversions from the Delta may affect aquatic species directly through entrainment and impingement or indirectly through changes in hydrologic conditions and aquatic habitat.

Results of operational studies indicate water stored during wet years in the Delta and additional carryover as a result of new storage can be used for fish and aquatic habitat improvements. There would be an increase in channel organic carbon close to the reservoir outlets that could benefit channel fisheries habitat. These ecological benefits need further evaluation.

Environmental water allocations during February through June and the resulting decreases in SWP exports would reduce the frequency and magnitude of reverse flows in the lower San Joaquin River. This would also contribute to the X2 position being located more within the western Delta, and increase Delta outflow. As a result, the quality and availability of aquatic habitat for fish would be improved. Additional water stored in the In-Delta Storage reservoir islands could be used to meet the ERP requirements.

When there is a significant decline in delta smelt abundance (FMWT < 239) during drought or extreme dry conditions, In-Delta Storage reservoir operations could help meet environmental needs. In-Delta Storage operations may result in additional upstream carryover storage, which can be used to release water to increase Delta outflow. Using In-Delta Storage to release water for ERP will also increase Delta outflow. Coordination between the fisheries regulatory agencies and project operators will be required to make supplies available for fisheries and habitat restoration during such most restrictive.

3.6.8 Impact of Climate Change

Climate change may result in higher winter flows and reduced spring runoff. Operation studies indicate that effect of climate change on In-Delta Storage operations would result in marginal change in water supplies (see Figure 3.13).

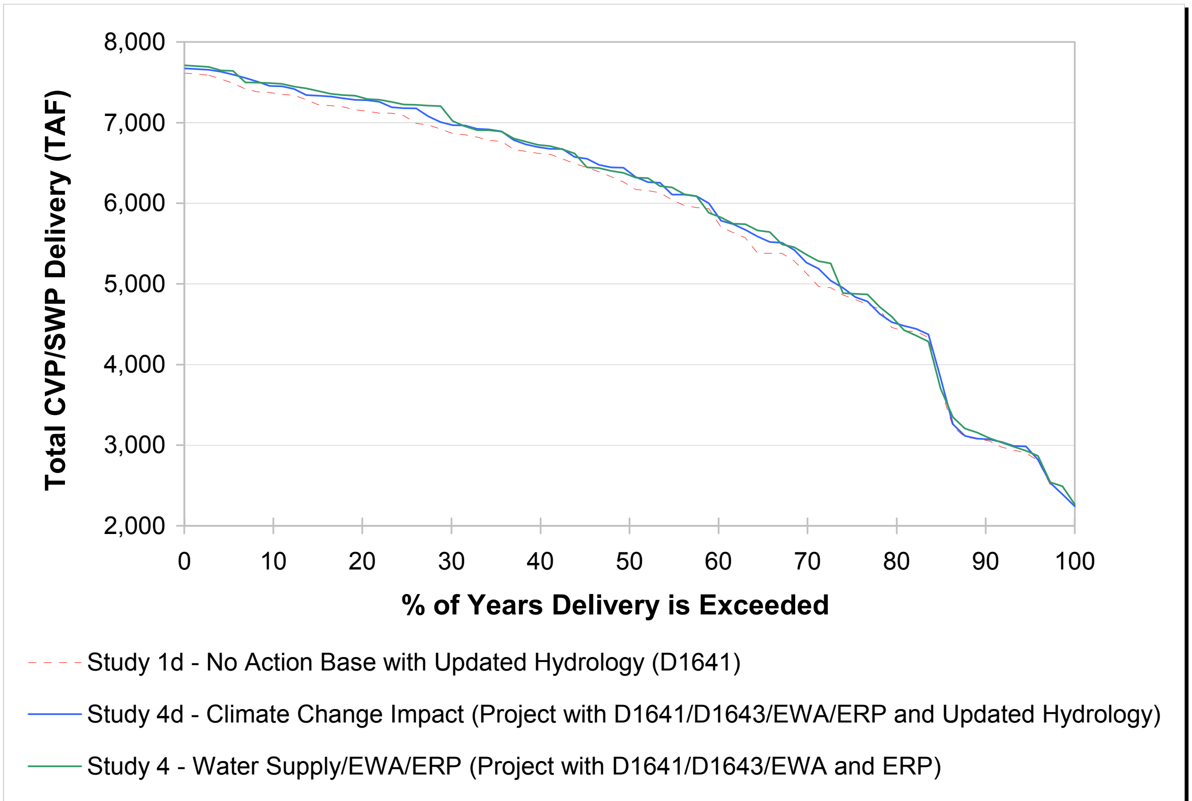


Figure 3.13: Long-Term Average Annual SWP/CVP Deliveries with Climate Change

3.6.9 Impact of D1643 Actions

Other storage projects being studied for the Bay-Delta Program have not yet progressed far enough in the process to have their own assigned operational requirements similar to D1643 for In-Delta Storage. Figure 3.14 shows that the In-Delta Storage Project could deliver about 100,000 acre-feet more benefits if it was not required to operate under the D1643 constraints.

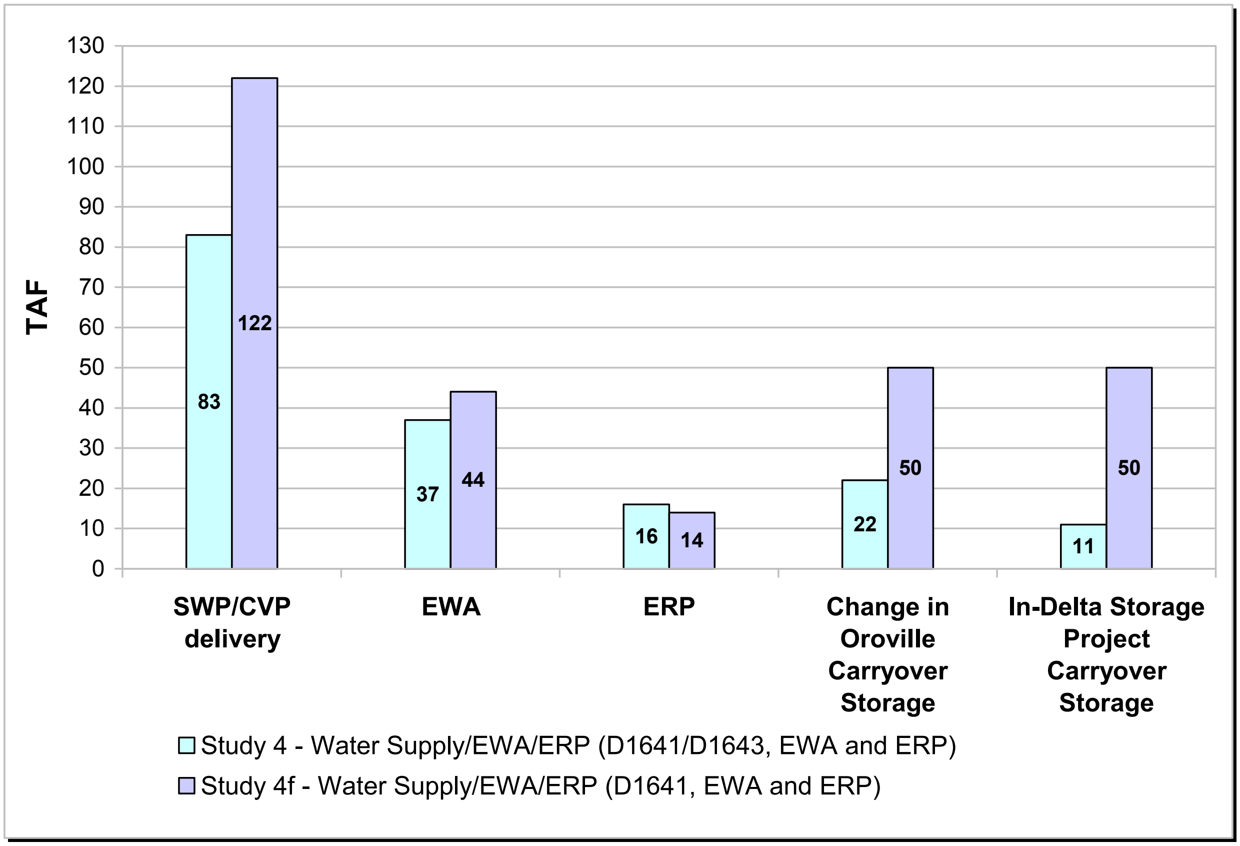


Figure 3.14: Long-Term Average Annual Changes in Water Supply

3.7 Conclusions and Recommendations

The analyses presented in this chapter included the effects of adding the In-Delta Storage Project facilities to the SWP/CVP system (with varying operations, such as the inclusion of EWA and ERP). Also presented were the impacts of: applying DOC constraints to the project; applying fisheries regulations; climate change; coordinated operation with expanded Los Vaqueros Reservoir; and SWRCB D1643.

Based on the results of the operational scenarios, the following conclusions have been made for the In-Delta Storage Project:

- Due to the project's strategic location, the operation of the island reservoirs would produce additional water deliveries to urban and agricultural water users and contribute to operational flexibility and increased reliability of the SWP and CVP systems.
- Resolution of water quality issues may be possible with circulation of water through the island reservoirs. Further studies are needed to establish effectiveness of the circulation process.
- Future operations can be refined during consultations with regulatory agencies for improvements in habitat quality and availability for fish and other aquatic organisms inhabiting the Bay-Delta system. The timing of environmental water allocations would be flexible

depending on the specific environmental benefit to be achieved (e.g. protection of spring-run chinook salmon and delta smelt).

- Due to the possibility of increased carryover storage in the upstream SWP and CVP reservoirs as a result of storing water in the Delta, CALFED's ERP and storage programs should work closely with regulatory agencies to maximize the program benefits and assure compliance of the Endangered Species Act.
- EWA studies for the In-Delta Storage Project show that In-Delta Storage could provide water needed to support the EWA program, enhancing the EWA ability to respond to real-time fisheries needs and eliminating the need to purchase a substantial portion of water, from other sources, needed by EWA each year.
- The In-Delta Storage Project and the Los Vaqueros Expansion Project were modeled, and evaluation indicates that both projects can be operated in coordination. Further evaluation of shared diversion points would result in additional benefits and cost savings. Comparative information on the other three CALFED storage programs (Shasta Enlargement, North of Delta Offstream Storage and Storage in the upper San Joaquin River Basin) could not be completed within the time limits of this study. Comparative information on all storage programs based on daily modeling is required to evaluate the benefits of joint operations. As these projects are at different levels of study, evaluations should be made based on common assumptions and overall benefit choices are to be defined.

Chapter 4: WATER QUALITY EVALUATION

4.1 General

Several modeling studies, literature searches and field experiments have been conducted to better understand water quality impacts associated with In-Delta storage. The current water quality standards in the Delta are based on the SWRCB Decision 1641. With SWRCB Decision 1643, additional requirements are imposed on the project operations. In addition, California Urban Water Agencies (CUWA), Contra Costa Water District (CCWD) and East Bay Municipal Utility District (BMUD) agreements with Delta Wetlands will prevent release of water that would degrade the beneficial uses of Delta water under the Water Quality Management Plan.

Information on water quality studies completed to assess the technical feasibility of the In-Delta Storage Project is presented in this chapter. These studies include: Water Quality Modeling Studies, Water Quality Field Investigations (Peat Soils and Biological Productivity Laboratory Studies), and Reservoir Stratification Studies. Details of these studies are presented in Draft Report on Water Quality, December, 2003.

Water quality investigations also focused on the recommendations made by the CALFED Science Panel during 2002 Review and later reviews in March and June 2003. As a result, reservoir stratification studies were added on to the original work plan for water quality studies. The Science Panel also held a CALFED Science Public Workshop for In-Delta Storage Project on August 20, 2003 and their report received by DWR on December 23, 2003 entitled “Review: In-Delta Storage Program CALFED Science Review Public Workshop Report (December 23, 2003)” is given in Appendix B. During the period from workshop in August, 2003 to report by Science Panel in December, 2003, DWR had already revised studies based on some of the Science Panel recommendations. The remaining recommendations will be included in future evaluations.

4.2 Water Quality Requirements

The water quality requirements are set forth in the SWRCB Decision 1643 and the WQMP as agreed by DW Properties and the CUWA, CCWD and EBMUD.

4.2.1 General Requirements

Discharges of water from the DW Project shall not cause: (1) any applicable water quality objective in a water quality control plan adopted by the SWRCB or by the RWQCB to be exceeded or (2) any recipient water treatment plant to exceed the maximum contaminant levels for disinfection by-products as set forth by EPA in Title 40, Section 141.12 and 141.30. The regulated classes of disinfection by-products are trihalomethanes, haloacetic acids, chlorite, and bromate (SWRCB, condition 14.a.). An uncertainty of ± 5 percent of the screening criteria will be assumed in order to determine if the DW Project has met one or more of the operational screen criteria.

4.2.2 Specific Requirements

There are also many specific water quality requirements that include criteria for total organic oxygen (TOC), chloride, disinfection byproducts (DBPs), dissolved oxygen (DO) and temperature. Specific criteria are briefly described below. A more detailed description is given in the Draft Report on Water Quality, December 2003.

TOC: The project shall not cause the TOC concentrations at a SWP, CVP, or CCWD pumping plant to exceed a limit of 4.0 mg/L, or cause an incremental increase in TOC concentration greater than 1.0 mg/L. In addition, discharges from Bacon Island and Webb Tract are limited based on the concentration of TOC in the reservoir water at the time of discharge.

Chloride: The project operation shall not cause an increase in chloride concentrations of more than 10 mg/L at any of CCWD's intakes or cause any increase in salinity of more than 10 mg/L chloride (14-day running average salinity) at any urban intake in the Delta. The project shall not cause or contribute to any salinity increase in an urban intake if the intake is exceeding 90 percent of the Rock Slough chlorine standard as defined in SWRCB Decision 1641. In addition, discharges from the reservoir islands are limited based on the concentration of chloride in the reservoir water. See the Water Quality Report for a more detailed description of chloride criteria.

DBPs: DW Project operations will be curtailed, rescheduled, or constrained to prevent impacts on drinking water quality if project operations cause or contribute to (1) modeled or predicted total trihalomethanes (TTHM) concentrations in drinking water in excess of 64 µg/L, as calculated in the raw water of an urban intake in the Delta or at the outlet of a water treatment plant or (2) modeled or predicted bromate concentrations in drinking water in excess of 8 µg/L, as calculated in the raw water of an urban intake in the Delta or at the outlet of a water treatment plant.

DO: Discharge of stored water is prohibited if the DO of stored water is less than 6.0 mg/L, if discharges cause the level of DO in the adjacent Delta channel to be depressed to less than 5.0 mg/L, or if discharges depresses the DO in the San Joaquin River between Turner Cut and Stockton to less than 6.0 mg/L September through November.

Temperature: Discharge of stored water is also prohibited if the temperature differential between the discharge water and receiving water is greater than 20º F, or if discharges will cause an increase in the temperature of channel water by more than: 4º F when the temperature of channel water ranges from 55º F to 66º F, 2º F when the temperature of channel water ranges from 66º F to 77º F, or 1º F when the temperature of channel water is 77º F or higher.

4.3 Water Quality Field Investigations

Field investigation during the feasibility stage of the study focused on better understanding of the reservoir biological processes concepts and variations in organic carbon due to peat soils and biological productivity. The field investigations included the following specific tasks to estimate the organic carbon loading from peat soils and biological productivity.

- Reviewed the literature on organic carbon loading in the Delta for information that may be applicable to In-Delta storage.
- Evaluated likely Organic Carbon (OC) concentrations and loads expected in storage water using mesocosms or physical models of the proposed reservoir islands. The experiments were extended to simulation of water circulation in reservoirs to resolve the water quality issues.
- Integrated results from field studies with mathematical models (CALSIM II, DSM2 and DYRESM) to resolve water quality issues and develop desired operations for overall system benefits.

4.3.1 Development of Conceptual Model

Disinfection byproducts (DBPs) such as trihalomethanes are an issue of concern for the California water system and the In-Delta Storage Program. Maximum contaminant levels and operational criteria are set by regulatory agencies to protect public health and research is being conducted to better understand and manage DBP precursors like total and dissolved organic carbon (TOC and DOC) at their source. DOC and particulate organic carbon (POC) in surface water can come from external or internal sources. For reservoir construction in wetlands, soil could be a dominant source of OC loading, at least initially. In order to adequately predict and mitigate both short-term and long-term impacts associated with flooding peat soils, it is important to understand not just the likely quantity of OC loading but also something about the quality or sources of that loading. Complex biological interactions and feedbacks are problems that can be addressed with careful and integrated use of mathematical, conceptual and physical models.

As part of DWR's evaluation of In-Delta storage, conceptual, mathematical and physical models were used to study likely water quality impacts from In-Delta storage. Mesocosms or physical models of the proposed reservoir islands were created to study the ecological processes driving OC loading. Results from these mesocosm studies were also integrated with a one-dimensional mathematical model of the Delta (DSM2) to study water quality impacts on a state water system scale.

The main goals of the mesocosm study were to reduce uncertainty surrounding estimates of likely OC loading rates for the proposed In-Delta reservoirs and to provide field data that are representative of the reservoir islands.

This mesocosm study was designed to meet specific needs and timelines of the program. The focus of the study was to reduce uncertainty surrounding estimates of likely rates for the process of OC loading in the proposed reservoir islands. The mesocosms were put together using naturally occurring water and biota. The objective of the experimental design was to include as many complex and interacting ecological factors that drive carbon dynamics in the Delta as possible. Study results in terms of net OC loading rates (such as interacting processes like abiotic leaching, microbial degradation, photooxidation and macrophyte growth and death decomposition) were considered together. Nevertheless, the use of water depth as a treatment variable with the mechanism of light attenuation driving submersed macrophyte growth in a replicated, controlled mesocosm experiment provided a start for fleshing out qualitative and quantitative differences in OC sources.

4.3.2 Materials and Methods

Mesocosm studies were conducted from March 2002 through December 2003 at the Municipal Water Quality Investigations Field Support Unit in Bryte, California. Four 3300 L (shallow) and four 6100 L (deep) tanks for mesocosm studies were put together using fiberglass tanks (1.5 m diameter and 1.8 or 3.4 m height respectively). The eight tanks were filled with 820 L (0.5 m depth) of peat soil, classified as Rindge series muck, collected from Bacon Island, California on March 5, 2002. Before adding the soil to the tanks, living plant material was removed and the soil was well mixed using a front end loader and backhoe. The Division of Natural Resources Analytical Laboratory at the University of California, Davis analyzed the soil for the following analytical groups: salinity, fertility, extractable micronutrients and exchangeable cations. Information on the lab and their analytical methods is available at http://danranlab.ucdavis.edu/. In addition to these analyses, the percent carbon (C), percent hydrogen (H) and percent nitrogen (N) content of the soil was determined using a Perkin-Elmer model 2400 CHN analyzer with acetanilide used as a standard. Soil fresh weight (fw) percent moisture, percent ash and percent organic matter (OM) as well as dry weight (dw) percent ash and percent OM and loose soil bulk density were determined before the soil was added to the tanks. The soil was compacted somewhat once inside of the tanks by walking on it as it was applied, leveled and adjusted to the 0.5 m depth.

Figure 4.1: View of Nine Fiberglass Tanks Used to Create Mesocosms

On March 12, 2002 the tanks were filled with Sacramento River water collected at West Sacramento using a 11,355 L water truck. Once filled, the depth of water over the peat soil was approximately 1.4 m in the shallow tanks and 2.9 m in the deep tanks. An additional 6,100 L tank was filled with river water only (no soil) and served as a control mesocosm.

The tanks were filled and drained according to typical modeled reservoir operations. January is the most typical month in which sufficient water is available in the Delta to fill the reservoirs. Filling the tanks in early March was less representative of typical operations than a January fill but the unavoidable result of logistics constraints. The theoretical reservoirs are usually emptied in June and July to a minimum depth of 0.3 meters. The minimum depth is maintained by topping-off diversions. Filling and draining of the reservoirs usually takes two to four weeks depending on the pumping plant design (number of pumps and capacity). Because of logistic constraints and the late start, the tanks were filled in one day on March 12, 2002. The tanks were emptied incrementally from July 29 through August 7 until a minimum depth of 0.3 m was reached, to better simulate how the reservoirs will be drained. As the tanks were drained, water pressure on the peat soil at the bottom was reduced and gas bubbles again escaped from the soil, mostly in the deep tanks. This study is currently underway.

Egeria densa is probably the most abundant submersed macrophyte in the Delta although good diversity and abundance data do not exist for submersed or other aquatic plants in the Delta (Jassby and Cloern 2000). After observing the onset of active growth of *Egeria* in the Delta, fragments were collected from Franks Tract and added to the tanks that same day, April 17, 2002, ten fragments (total 80 g f.w.) were added to each tank. Naturally occurring invertebrates, epiphytic algae, eggs or other organisms on the *Egeria* fragments were not removed and the fragments were transported in coolers filled with Delta water to minimize mortality. On May 1, 2002 eleven adult Threespine stickleback were added to each tank. These fish were added because they are naturally occurring in the Delta and they satisfied mosquito concerns of the county vector control district.

Maximum and minimum water temperatures in the tanks were recorded every two weeks and ranged from 8 to 34 C during the study. To simulate wave action and mixing on the surface of the reservoirs and to ensure dissolved oxygen (DO) concentrations remain high enough for fish, small aquarium air stones (4 cm-length x 1.3 cm width) were placed five cm under the water surface. The lowest DO concentration observed in the tanks was 5.7 mg and occurred before the aeration stones were installed.

Water samples were taken from a depth of 0.3 m from each tank every two weeks using a Van Dorn sampler. Samples were analyzed using standard methods by the DWR Bryte Analytical Laboratory (http://wq.water.ca.gov/bryte/) for the following water quality parameters: Total Organic Carbon by combustion (TOC), Dissolved Organic Carbon by combustion (DOC), UV Absorbance at 254nm (UV254), Turbidity, pH, Total Mercury, Total Kjeldahl Nitrogen (TKN), Dissolved Ammonia, Dissolved Nitrite and Nitrate, Total phosphorus and Ortho-phosphate. In addition to these water quality measures, the following field data were collected at the time of sampling: Temperature, Dissolved Oxygen (DO) and Secchi Depth. Subsamples of juvenile fish trapped in 2002 were analyzed for whole fish total mercury concentrations by the California Department of Fish and Game Water Pollution Control Laboratory in Rancho Cordova, California. These analyzed fish were born in the mesocosms, and observed as fry at a size of approximately two to three cm.

During the study period, March through December 2002, evaporation less precipitation was approximately 50 cm in the mesocosms. The water lost to evaporation was replaced with Sacramento River water collected from the same West Sacramento location.

In the 2003 study, the new circulation operation for the reservoir islands was simulated in the operation of the mesocosms. Figure 4.3 shows DOC concentrations in the mesocosm water (preliminary data). Declines in DOC are due to dilution from filling and circulation. The tanks were filled in thirds over a three month period starting in January 2003. For example if there was 2.1 m head space at the beginning of the study in late January, 0.7 m or 1/3 of the storage capacity was added. Then at the end of February the second third (0.7 m) was added and at the end of March the final third was added and the mesocosms were then full. The percent (%) of water circulated or exchanged in the mesocosms is shown by the arrows in Figure 4.3. For example, if there was one meter of water in a mesocosm and 0.25 meters of water was drained and replaced with Sacramento River water this was a 25% circulation. Figure 4.3 shows relatively flat organic carbon concentrations during the March through July storage period because the exchange or circulation rate was approximately in balance with OC loading rates.

While the circulation operation in 2003 was different than 2002 mesocosm hydrology (see Figure 4.2 showing mean 2002 DOC concentrations), preliminary results from the 2003 study suggest that organic carbon loading rates are consistent with 2002 rates. Also, little POC was observed in 2003 as in 2002 i.e., the TOC:DOC ratio appears to be close to one in both years (TOC and other water quality data have not yet been fully tabulated and analyzed). Figure 4.4 shows the DOC concentrations during the March through July storage period as in Figure 4.3 but standardized to a one meter water depth to account for dilution effects from refilling and circulation operations. These preliminary data are consistent with the OC loading algorithm used in DSM2**.** The OC loading algorithm as implemented in DSM2 assumed a zero rate for OC loading in the winter months. The preliminary 2003 data shown in Figure 4.5 for the winter months of January and February are also consistent with this assumption. After the tanks were drained to a depth of 0.3 meters water was no longer circulated, i.e. the mesocosm hydrology was the same as in 2002 after draining. Therefore, the 2003 January-February data do not need to be standardized for comparison with 2002 data. Figure 4.6 shows DOC concentrations as measured (not transformed) for the non-storage or drained period. Again, preliminary 2003 results are consistent with the OC growth rate developed from the 2002 study. Additional 2003 data like trihalomethane formation potential and UV absorbance have not been analyzed for the 2003 data.

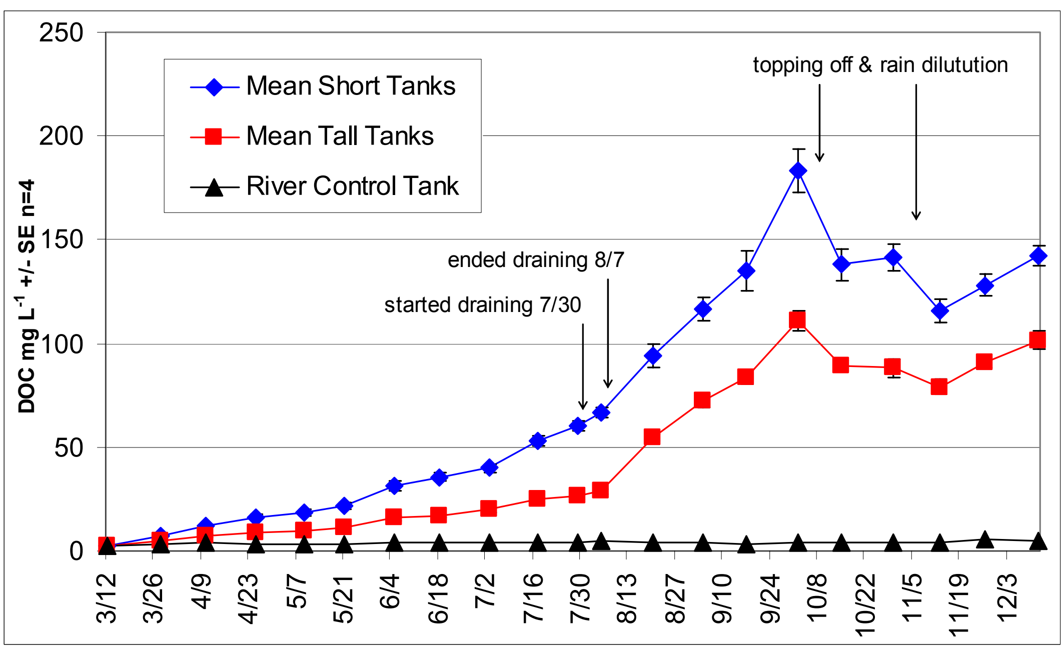


Figure 4.2: Mean 2002 DOC Concentrations in Mesocosms

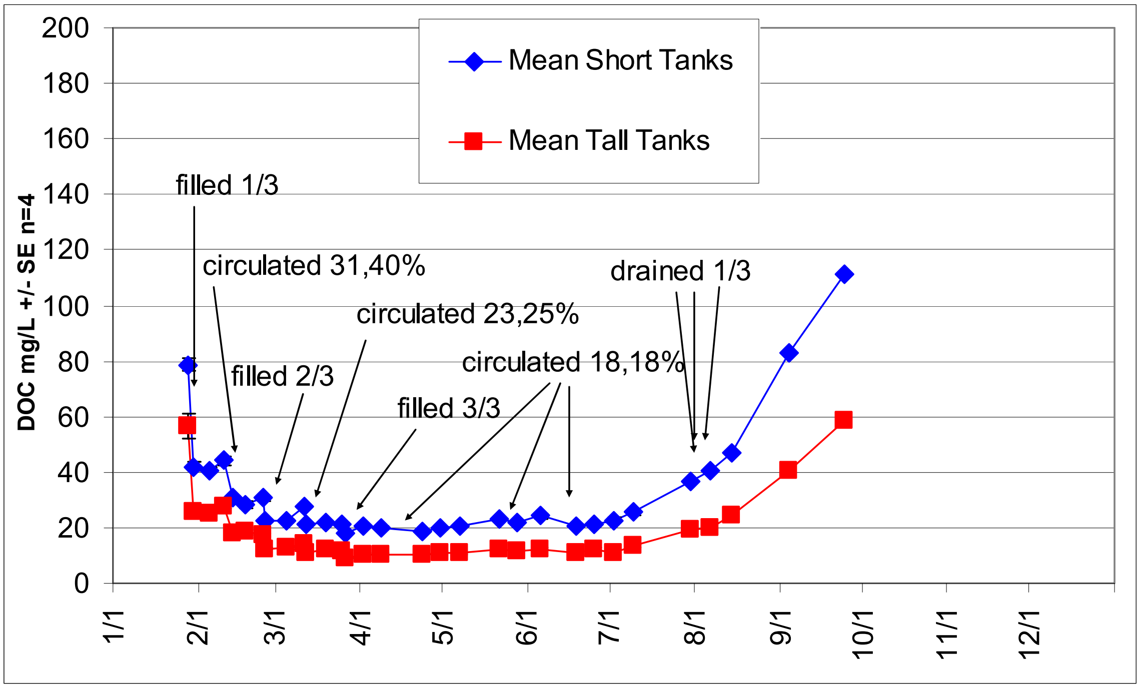


Figure 4.3: Mean 2003 DOC Concentrations in Mesocosms

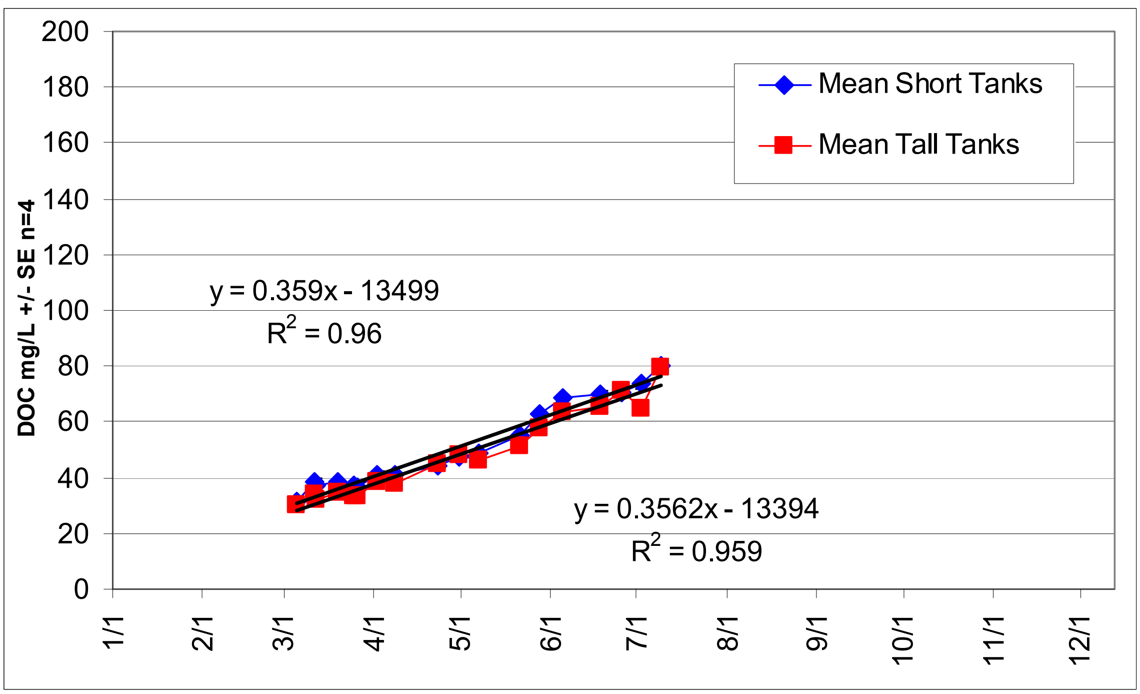


Figure 4.4: Mean 2003 March-July Storage Period DOC Concentrations in Mesocosms
(standardized to a one-meter water depth).

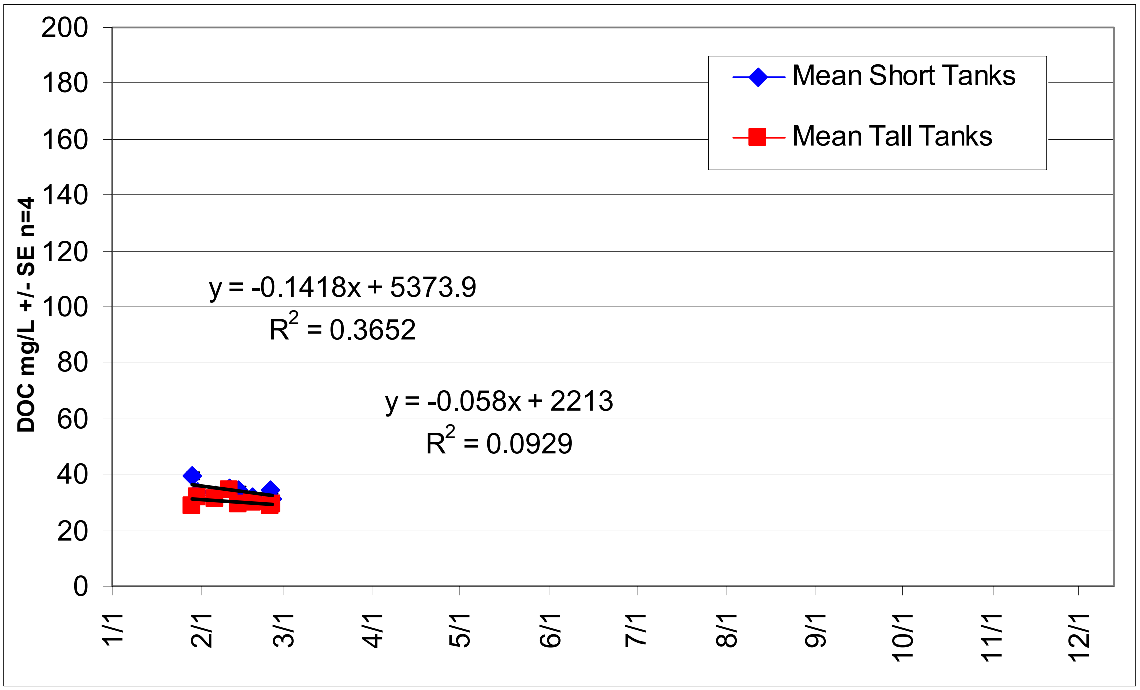


Figure 4.5: Mean 2003 Winter DOC Concentrations in Mesocosms
(Standardized to a one meter water depth)

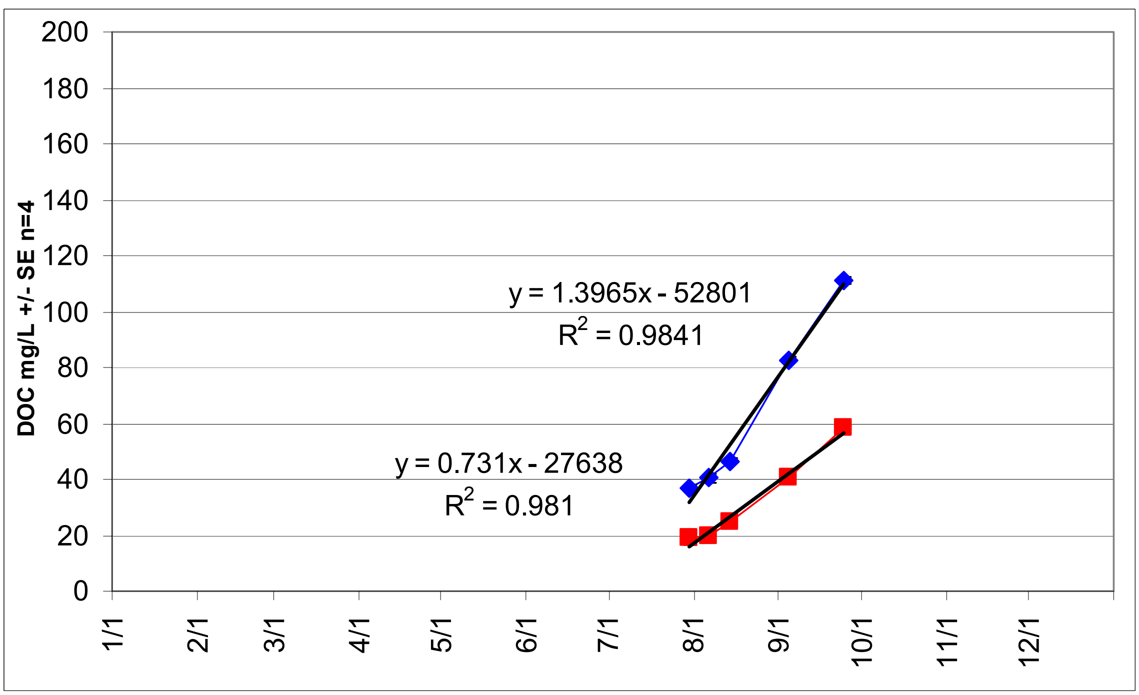


Figure 4.6: Mean 2003 Drained Period DOC Concentrations in Mesocosms
(These data are DOC concentrations as measured i.e. not standardized. In order to standardize slopes use m*0.3 to get OC loading rates of 0.42 and 0.22 gC/m^2/d respectively.)

Predicting organic carbon loading in the proposed in-Delta reservoir islands has been a challenge for over a decade. The first estimates were a part of a 1990 Delta Wetlands Inc. draft EIR (DW 1990), mostly qualitative and based on comparisons to Delta island agricultural drainage. Estimates in this and subsequent EIRs were also limited in that algal and vascular aquatic plant productivity (bioproductivity) was not adequately considered. In recent years, DWR has conducted studies in order to reduce uncertainty and make a recommendation on the project. Much still needs to be done in order to develop process-level mechanistic models of the reservoirs especially ones that can be used to accurately predict water quality in the reservoirs and at downstream drinking water intakes. Nevertheless, this mesocosm study is the latest step in an ongoing and integrative process to reduce uncertainty.

4.3.3 Use of OC Field Data in Modeling

Comparison of the mean 2002 and 2003 OC concentrations in the mesocosms shown in Figures 4.2 through 4.6 (respectively) indicates similar OC values in both years. The annual average areal loading rate is on the order of 100 gC/m^2/yr. The OC growth rates shown in Table 4.1 were used in the DSM2 model runs. These rates vary over the course of the year and are consistent with this annual average areal loading rate of about 100 gC/m^2/yr.

Table 4.1: Organic Carbon Growth Rates (gC/m2/day) Based on Field Data Analysis

Island	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Bacon Island	0.59	0.00	0.00	0.00	0.00	0.30	0.30	0.30	0.35	0.35	0.59	0.59
Webb Tract	0.59	0.00	0.00	0.00	0.00	0.30	0.30	0.30	0.35	0.35	0.59	0.59

4.4 Delta Simulation Model (DSM2) Modeling Studies

The water quality modeling studies were conducted with the Department's Delta Simulation Model (DSM2). The following work was performed in support of the modeling studies in order to assess the impact of project operations under D1643 and WQMP:

- Revise the organic carbon growth algorithm in DSM2 to better address carbon loading from peat soils and biological productivity.
- Compare island reservoir organic carbon dynamics from the new algorithm with old logic.
- Revise estimates for likely organic carbon concentrations in storage water in comparison to the No Action Base conditions.
- Create dispersion rules for CALSIM II circulation studies and check final reservoir DOC and TOC at the urban intakes for the final CALSIM II run.
- Compare water quality constituents under No Action Base conditions with In-Delta Storage Project operations under D1643 and WQMP.
- Provide input to Reservoir Stratification studies.

Three DSM2 daily time step 16-year planning studies were run in HYDRO and QUAL based on the proposed operations for the islands: Webb Tract and Bacon Island. The Delta inflows, exports and island operations used in these studies were provided from the CALSIM II Daily Operations Model (DOM). A listing of the DSM2 / CALSIM II scenarios is as follows.

Study	Basic Study Objective	CALSIM II Operational Constraints
Study 1	No Action Base	D1641
Study 4[1]	Water Supply / EWA / ERP	D1641 / D1643 / EWA & ERP
Study 4b	DOC Dilution through Circulation	Study 4 with DOC Constraints

[1]Study 4 was used to develop fingerprinting results, but no water quality results from study 4 will be presented.

All three studies were based on separate CALSIM II runs. However, CALSIM II's study 4b includes information from DSM2's study 1 and study 4. The interaction between CALSIM II and DSM2 is illustrated in Figure 4.7. Study 1 provided the base line DOC concentrations at the urban intakes. Study 4 used fingerprinting information to provide the project island volume - flow relationships that were integrated into CALSIM II in order to constrain project releases to meet the DOC standards consistent with the State Water Resources Control Board (SWRCB) water rights decision D1643. Due to time constraints, study 4 was not used to analyze DOC or EC based on the study 4 CALSIM II operations.

Details of these DSM2 modeling studies to assess the feasibility of the project operations are presented in the December 2003 Draft Report on Water Quality Investigations.

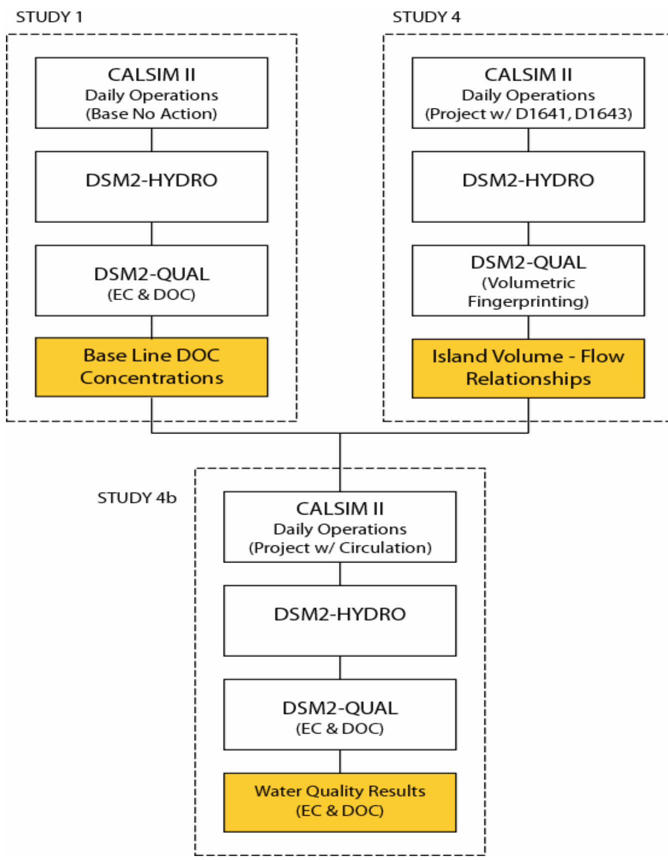


Figure 4.7: Study Methodology for Modeling

4.4.1 Simulated Constituents

The DSM2 model simulation was conducted for DOC and was modeled as a conservative constituent. The DSM2 model has also been used to simulate DO and Temperature. The behavior of other conservative constituents (TOC, BROMIDE, Chloride, UVA and TTHM) could be derived using the statistical the statistical relationships between EC, DOC and the conservative constituents.

For example, DOC was used as a surrogate for TOC and EC was used as a surrogate for chloride and bromide in the model simulations.

Statistical relationship between ultraviolet absorbance at 254 nm (UVA) and DOC at the urban intakes was developed using results from previous studies. Simulated DOC and bromide (converted from EC) values, computed UVA values, and approximate water temperatures were used to compute TTHM concentrations. The relationship between the DOC, EC and other constituents are positive. This means when the DOC increases so does the TTHM and UVA and vice versa. Thus, any improvement/decrease in the DOC at any location will lead to corresponding improvement/decrease of other constituents.

Details of DSM2 application and analyses for DOC and other constituents (EC, UVA, Chloride, Bromide, UVA and TTHM) are given in December 2003 Draft Report on Water Quality.

4.4.2 DSM2 Physical Representation of the Project Islands

DSM2 treats reservoirs as tanks with constant surface areas and variable depths, thus elevation (stage) in the reservoirs is a linear function associated with net flows into (or out of) the reservoirs. The DSM2 surface area for each reservoir was fixed such that when at a depth of 20 ft that each island's storage capacity would approximate its design storage capacity. The configuration of the project islands as modeled by DSM2 is shown in Table 4.2.

Table 4.2: DSM2 Project Island Configuration

Island	Design Storage Capacity (TAF)	DSM2 Surface Area (acres)	Northern Integrated Facility DSM2 Node	Southern Integrated Facility DSM2 Node
Bacon Island	120	5,450	128	213
Webb Tract	118	5,370	40	103

In order to prevent DSM2 from drying up (DSM2 does not support wetting and drying, thus some amount of water must always be kept on every channel or reservoir in the model), a dead pool of 0.1 ft was added. The initial depth of the active storage pool at the start of each DSM2 simulation was determined by relating the CALSIM storage to the DSM2 storage-depth relationship.

Two integrated (diversion and release) facilities were used on each island to fill and empty the island reservoirs. The location of the each integrated facility in DSM2 corresponds with the approximate field location (see Figure 4.8 and Table 4.2).

4.4.3 Delta Barrier Operations

The four South Delta barriers, Middle River, Old River, Grant Line Canal (west), and Head of Old River at the San Joaquin River, were modeled as permanent barriers. The purpose of the first three barriers is to improve the water levels in the South Delta. The Head of Old River at the San Joaquin

River barrier is designed to prevent fish from swimming down the Old River and ending up at the SWP and CVP pumps.

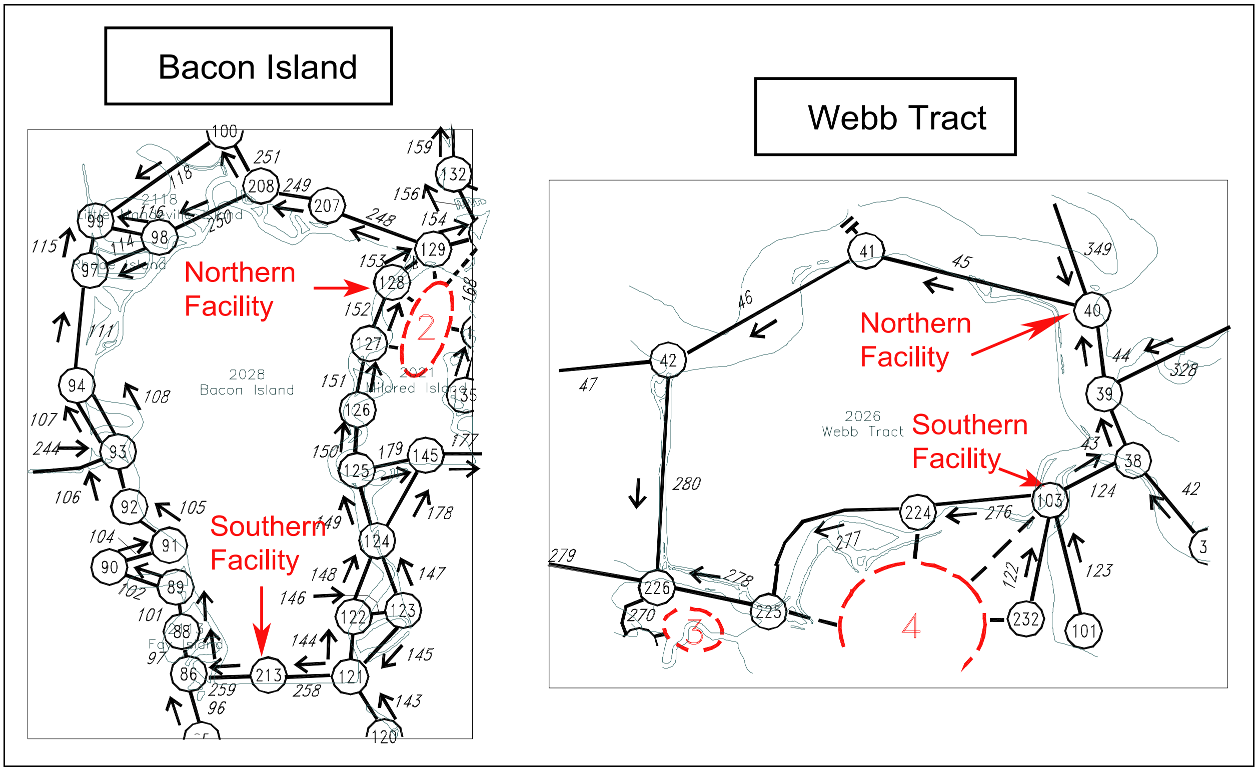


Figure 4.8: DSM2 Grid Surrounding Bacon Island and Webb Tract.

All four barriers were treated as gated weirs. Flow could pass in either direction of the barriers when the gates in the barriers were not operating. When the gates were operating, the barriers restricted flow downstream through the barrier.

Details on operations for all four barriers are given in December 2003 Draft Report on Water Quality. The same operations were used in the base and alternative simulations. Although the Old River and Middle River barriers used the same schedule of operations, the physical configuration of the two barriers was different.

4.4.4 Delta Water Quality

Water quality inputs, EC and DOC, were applied in DSM2-QUAL to the flows generated in DSM2-HYDRO at the river and ocean Delta boundaries and at interior Delta locations. With the exception of EC at Martinez, the water quality concentrations for both EC and DOC at all of the flow inputs into the Delta were based on standard monthly varying DSM2 planning studies concentrations (i.e the concentrations themselves did not change between studies). However, the relative amount of each constituent brought into the Delta is variable between studies. The amount at each boundary input is the product of the concentration assumed for that boundary and the volume of water that enters at the boundary.

EC and DOC were simulated as a conservative constituent while in the Delta channels. DSM2 has been calibrated and validated for EC and validated for DOC (insert reference to EC and DOC calibration and validations). DOC from the ocean boundary at Martinez and Stockton Waste Water Treatment Plant releases were considered negligible (i.e. 0 mg/L). The standard monthly varying DSM2 16-year planning study DOC concentrations applied at the remaining DSM2 flow input boundaries were generated based on historical DOC – flow relationships.

4.4.5 Project Island EC

EC is simulated as a conservative constituent in DSM2. Changes to the EC concentration on the project islands due to a filling operation are a function of both the volume of water already on the island, and the volume of water diverted to the island, and the concentrations associated with these volumes respectively. A simple mixing equation is used to blend the concentrations of incoming water with the concentrations of existing water. Since DSM2 is a 1-dimensional model, water inside the reservoirs is assumed to be uniformly mixed.

When there is no diversion into the island, the EC concentration on the island will not change. Although the small evaporation "topping-off" diversions will change the project island EC, the volume of water diverted onto the island is small enough that these changes are minor.

Releasing water from the islands will have no impact on the EC concentration inside the reservoirs. However, the concentration in the adjacent channels will change. While the volume of water released may have a significant impact on the EC concentration in the neighboring channels, the net water added to the Delta itself is small. The impact on local stage should be minor (i.e. storage in the channel should be about the same). The change in local channel EC will be a function based on the amount of water released and the amount of channel water that is not displaced by the project island releases and the respective concentrations associated with both volumes of water.

The EC associated with seepage was determined by running study 4b in an iterative process. In the first QUAL simulation, the EC associated with seepage return flows was set to 0 umhos/cm. The instead of setting EC to 0 umhos/cm, the EC for each island from the first iteration was assigned as the concentration of the seepage return flows. Since the EC concentration assigned to the seepage flows returned to the islands was the same concentration as the water removed by seepage, seepage had no impact on island EC. This iterative process was necessary in order to use the exact same hydrodynamic results that were used when modeling DOC.

4.4.6 Project Islands DOC

The concentration inside either island is both a function of the mixing associated with diversions to the islands (similar to how EC is mixed), the production of organic carbon mass from algae and wetlands plants, and the addition of organic carbon mass due to leaching and microbial decay of the peat soils. The increase in DOC concentration associated with storing water on the peat soil islands is accounted for in QUAL by a DOC growth algorithm (Mierzwa *et al.*, 2003). These relationships are based on field studies that took into account both the increases in organic carbon mass due to decay and leaching as well as the increases due to production of new organic carbon from algae and wetland plants. The organic carbon growth rates shown in Table 4.3 vary over the course of the year and were based on field experiments as described in Section 4.3.

Table 4.3: Project Island Organic Carbon Growth Rates (gC/m2/day)

Island	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Bacon Island	0.59	0.00	0.00	0.00	0.00	0.30	0.30	0.30	0.35	0.35	0.59	0.59
Webb Tract	0.59	0.00	0.00	0.00	0.00	0.30	0.30	0.30	0.35	0.35	0.59	0.59

The DSM2 was calibrated and validated for flow, stage and electrical conductivity (EC) in collaboration with the DSM2 Interagency Ecological Program Project Work Team. The model was also successfully validated for the transport of DOC. DSM2 simulations covered the 16-year period October 1, 1975, through September 30, 1991. The performance of the DSM2 model in simulating flow was examined by the Bay-Delta modeling forum through independent peer review process, for a variety of geometry, initial and boundary conditions, the DSM2 model performed well and conserved both mass and momentum. Details of the review process and model performances can be found at http://www.cwemf.org/1-DReview/default.htm.

4.4.7 Seepage

The seepage flows passed through the organic carbon rich peat soils and were returned to the project islands using interceptor wells. The DOC concentrations of these seepage returns represent the amount of organic carbon that would be entrained in the seepage flows and moved back onto the islands. No direct field tests have been conducted to separate out which organic carbon sources contribute to seepage return quality. Instead of using the same iterative approach that was used when modeling EC seepage return quality, it was assumed that the DOC concentration associated with the seepage return flows was 20 mg/L. It is important to note that seepage only occurs when the stage in an island is greater than -1 ft. At times the DOC concentration of water on a project island is greater than 20 mg/L, and at other times the DOC concentration is less than 20 mg/L. The significance of this assumption can be ascertained by examining the organic carbon concentration on the project islands and the amount of water passing through the interceptor well system. Because the elevation of most Delta islands is lower than the low tide water surface in the channels that surround the islands, seepage usually occurs from the channels onto the islands. However, when water is stored on the In-Delta Storage Project islands, the gradient of ground water flow between the neighboring channels and islands will at times be reversed. Water from the island reservoirs would move to the channels, carrying with it organic carbon from the island peat soils. To prevent this reverse seepage, the In-Delta Storage Project will use interceptor wells to collect water moving from the islands to the channels. After collecting the water, the wells will return the seepage flows back to the island.

Although there is no net change in storage due to seepage when using wells to return water lost due to seepage, the collected water will have a high concentration of organic carbon. In order to account for the addition of this organic carbon to the island reservoirs, seepage losses and returns were provided by DWR's Integrated Storage Investigations group for both Bacon Island and Webb Tract. The seepage flow rates used in DSM2 are summarized in Table 4.4. Since DSM2 treats reservoirs as buckets (i.e. the surface area is fixed and the volume is a function of stage), the seepage losses were not divided between the different wells, but instead were taken directly from the island reservoir. The return flows from the interceptor wells were added back to the reservoirs. There is no interaction of the seepage water with the neighboring channels.

Table 4.4: Summary of Project Island Seepage for Study 4b

Island	Seepage Flow Rate (cfs)	% of Time w/ Seepage in 16-yrs (%)	Ave. CALSIM II Stage w/ Seepage (ft)	Max. CALSIM II Stage w/ Seepage (ft)
Bacon Island	9.8	24.9%	3.2	4.0
Webb Tract	8.3	22.1%	3.5	4.0

In the field, seepage losses will occur only at times when the stage in the island reservoirs is higher than the stage of the surrounding channels; however, it was necessary to assume a fixed water level for each island to trigger when seepage would occur. Seepage flows resulted only when the stage results from CALSIM II were greater than or equal to -1.0 ft. In situations where the project islands were partially full, this reverse seepage would not occur. The percentage of time during the 16-year DSM2 planning study that there was any seepage on the islands is shown in Table 4.4.

4.4.8 Operation Strategies: Circulation

One of the primary differences between study 4 and study 4b is the use of a circulation operation in study 4b in order to improve the water quality in the project islands. Circulation operations take advantage of the fact that both islands have two integrated facilities, by diverting water through on facility while simultaneously releasing water through the other facility. The net difference in flow rates shows if water is being stored or released from the islands. For this particular circulation simulation, CALSIM limited the circulation to 500 cfs. Like the standard release operations, releases made under a circulation operation still are subject to all Delta water quality standards.

4.5 Results of Model Studies

Using the DSM2-QUAL fingerprinting, EC, and DOC results, the change in water quality at four Delta urban intakes: CCWD intake at Rock Slough, CCWD Los Vaqueros Reservoir intake on the Old River, SWP Banks Pumping Plant, and CVP Tracy Pumping Plant, was evaluated. The fingerprinting results were used to develop DOC constraints in CALSIM II. This gives insight into the internal flow patterns in the Delta. Chloride concentrations at the urban intakes were calculated based on observed EC-chloride regressions. DOC at the intakes was reported as simulated, but then DOC and EC were used to calculate total trihalomethane (TTHM) and bromate formation.

4.5.1 Fingerprinting

Prior CALSIM / DSM2 In-Delta storage studies made use of DSM2's ability to track particles through DSM2-PTM to develop flow based DOC constraints in CALSIM II (Mierzwa, 2003). Based on conclusions made during the testing of the previous island-particle fate relationships, a new methodology for estimating the amount of organic carbon reaching the urban intakes in CALSIM was developed.

As described by Anderson (2002), fingerprinting can be used in DSM2 to estimate the original sources of water at a given location. A fingerprinting simulation was set up using study 4 where the diversions to the project islands were treated as a sink of water much like an export, and the releases from the project islands were treated as new sources of water much like a river inflow to the Delta.

Each of the inflows into the Delta, including the Martinez stage boundary and releases from each project island, was assigned a unique conservative tracer constituent and then simulated in QUAL independently of the other boundaries. The total amount of water to the urban intakes would come from the Sacramento River, San Joaquin River, Bacon Island, Webb Tract and all other smaller sources for the four urban intakes. As expected, the relative contribution of the San Joaquin River water is a function of time of year and proximity to Vernalis. The fingerprinting plots also illustrate the length of time that water released from the projects remains in the vicinity of the urban intakes.

4.5.2 Chloride at Urban Intakes

The EC results from DSM2-QUAL were converted to chloride concentrations at the four major South Delta urban intake locations. These equations for converting modeled EC to chloride concentration for Contra Costa Water District's Rock Slough diversion (Contra Costa Pumping Plant #1), three Delta urban water supply intakes; CCWD's Los Vaqueros Reservoir (LVR) intake on the Old River, the SWP's Banks Pumping Plant intake, and the CVP's Tracy Pumping Plant are given in December 2003 Draft Report on Water Quality.

The 16-year minimum, average, and maximum daily averaged chloride at the four urban intakes is shown below in Table 4.5. The chloride concentration associated with the 10th, 25th, 50th, 75th, and 90th percentiles for each location is also shown. These percentile concentrations were computed by ranking the 5,844 daily average concentrations for each location in ascending order, and then associating a concentration with a specified percentile. The 10th percentile represents the 584th lowest concentration, the 50th percentile represents the median concentration, and the 90th percentile represents the 5260th lowest concentration (or the 584th highest concentration).

Table 4.5: Summary of Daily Averaged Chloride (mg/L) at Urban Intakes

Urban Intake	Study	Min	Ave	Max	Percentiles				
					10th	25th	50th	75th	90th
RS	Study 1	8	102	318	31	42	81	153	200
	Study 4b	8	103	309	32	43	82	157	201
LVR	Study 1	3	81	257	20	32	68	123	160
	Study 4b	3	82	248	21	33	68	125	160
SWP	Study 1	3	74	215	19	34	67	109	139
	Study 4b	3	74	208	19	34	67	111	148
CVP	Study 1	3	85	223	16	50	84	121	148
	Study 4b	3	86	222	16	50	84	121	148

Although both study 1 and study 4b violated the current (D1641) 250 mg/L chloride Delta water quality standard at Rock Slough and Los Vaqueros Reservoir intake, the 90th percentile results show that for 90% of the 16-year simulation that chloride was less than 201 and 160 mg/L at each location respectively. In other words, the maximum (and minimum) values represent extreme events. Furthermore, though the maximum chloride concentrations decreased in study 4b at all four locations, the percentile results for study 1 and study 4b at each of the four locations were similar. The exception to this trend would be the 75th percentile for Rock Slough, where chloride increased from 153 to 157 mg/L.

The Water Quality Management Plan limited the operation of the In-Delta Storage Project such that the 14-day running average of chloride would not exceed 90% of the current D-1641 250 mg/L chloride standard. A summary of the 14-day average chloride results is presented in Table 4.6. Taking a 14-day average of the daily chloride results did not make any significant changes in the chloride concentration summary statistics.

Table 4.6: Summary of 14-Day Average Chloride (mg/L) at Urban Intakes

Urban Intake	Study	Min	Ave	Max	Percentiles				
					10th	25th	50th	75th	90th
RS	Study 1	9	102	302	32	42	81	153	198
	Study 4b	9	103	291	33	43	82	157	197
LVR	Study 1	3	81	246	21	33	68	123	158
	Study 4b	3	82	237	21	34	68	125	157
SWP	Study 1	3	74	214	20	34	67	110	138
	Study 4b	3	74	207	20	35	67	112	138
CVP	Study 1	3	85	217	17	49	84	121	147
	Study 4b	3	86	217	16	50	84	122	147

All of CCWD's diversions were assumed to be at Rock Slough. The sensitivity of this assumption on EC and chloride is unknown. However, the daily averaged and 14-day average chloride results shown in Tables 4.6 and 4.7 show that the chloride at Rock Slough was higher than the chloride at the other three urban intakes.

As shown in Table 4.7, though the 16-year maximum increase in chloride violated the 10 mg/L standard at each of the four locations, the 90% chloride concentrations was less than 10 mg/L at all of the intakes. The average change in chloride concentrations is slightly higher than the median (50% results), thus implying the presence of a few extreme values or outliers.

Table 4.7: Summary of Change in 14-Day Ave. Chloride (mg/L) at Urban Intakes

Urban Intake	Min	Ave	Max	Percentiles				
				10th	25th	50th	75th	90th
RS	-12.5	1.2	40.7	-3.6	-0.7	0.4	2.1	5.8
LVR	-12.2	0.9	32.1	-3.3	-0.9	0.2	1.7	5.1
SWP	-15.4	0.6	23.5	-3.1	-0.8	0.1	1.4	4.2
CVP	-21.8	0.4	17.5	-2.4	-0.7	0.1	1.1	3.2

4.5.3 DOC at Urban Intakes

The 14-day average DOC constraints called for by the Delta Wetlands WQMP were calculated every day as the average of the 14 previous days. This was done not only to remain consistent with CALSIM, but also under the assumption that forecasting and operations would make use of the previous 14 days worth of field and modeling data. A summary of the 14-day averaged DOC concentrations is shown in Table 4.8.

Table 4.8: Summary of 14-Day Average DOC (mg/L) at Urban Intakes

Urban Intake	Study	Min	Ave	Max	Percentiles				
					10th	25th	50th	75th	90th
RS	Study 1	2.1	3.3	10.8	2.2	2.4	2.9	3.7	5.0
	Study 4b	2.3	3.7	10.9	2.7	2.9	3.4	4.1	5.2
LVR	Study 1	2.2	3.6	10.6	2.5	2.7	3.3	4.2	5.3
	Study 4b	2.5	4.2	10.6	3.0	3.4	3.9	4.8	5.6
SWP	Study 1	2.3	3.7	10.8	2.6	2.9	3.4	4.2	5.3
	Study 4b	2.7	4.4	10.8	3.3	3.6	4.1	4.9	5.8
CVP	Study 1	2.4	3.7	11.0	2.8	3.0	3.4	4.0	5.1
	Study 4b	2.7	4.3	11.0	3.3	3.5	3.9	4.7	5.6

Violations of the Water Quality Management Plan (WQMP) DOC standard are not based on the 14-day averages, but instead on the difference between the new In-Delta storage operation and the modeled base case. According to the WQMP, when the modeled base case DOC is less than 3 mg/L or greater than 4 mg/L, the maximum increase in DOC at any urban intake is 1 mg/L. When the base case DOC is between 3 mg/L and 4 mg/L, the 14-day average DOC at any urban intake can not exceed 4 mg/L (in other words, the maximum allowed increase is the difference between 4 mg/L and the base case). The incremental WQMP constraint is illustrated below in Figure 4.9.

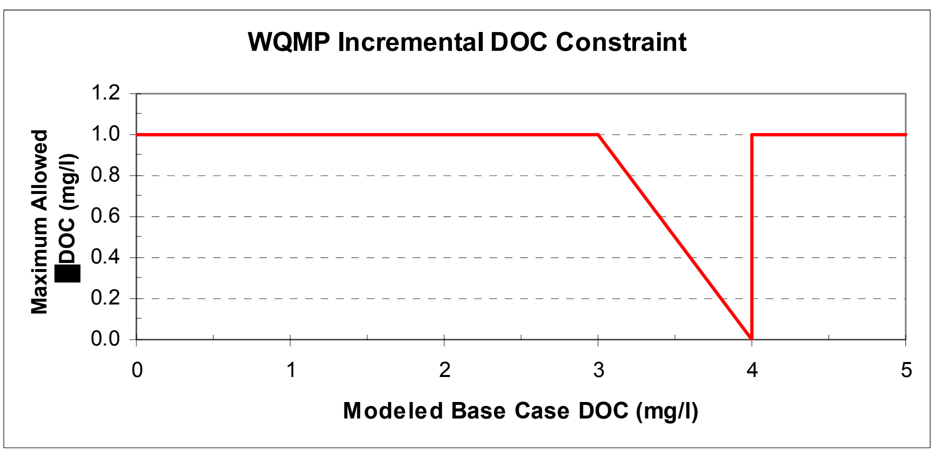


Figure 4.9: WQMP Incremental DOC Constraint.

The 16-year minimum, average, and maximum change (study 4b - study 1) in the 14-day average DOC at the urban intakes is shown in Table 4.9. The 10th percentile results show no impact due to the operation of the project. With the exception of Rock Slough, the 90th percentile results are greater than 1 mg/L. It is important to note that the WQMP DOC constraint listed above varies between 0 and 1 mg/L, thus the percentile results can only be used to estimate the magnitude of the change in DOC due to the operation of the project, but not the frequency that the WQMP DOC constraint is exceeded.

Table 4.9: Summary of Change in 14-Day Ave. DOC (mg/L) at Urban Intakes

Urban Intake	Min	Ave	Max	Percentiles 10th	25th	50th	75th	90th
RS	-0.6	0.4	2.6	0.0	0.1	0.3	0.6	0.8
LVR	-0.6	0.5	3.3	0.0	0.1	0.4	0.8	1.2
SWP	-0.4	0.6	2.7	0.0	0.1	0.5	1.0	1.3
CVP	-0.2	0.5	4.4	0.0	0.0	0.4	0.8	1.3

4.5.4 TTHM at Urban Intakes

Like the chloride and DOC constraints, the impact of total trihalomethane (TTHM) formation is measured by increases in the project alternative when compared to the modeled base case concentration. TTHM is not directly modeled in DSM2. The WQMP established an incremental standard (described below) and agreed upon the basic modeling approach to be used to calculate TTHM. TTHM is calculated as a function of EC, DOC, and water temperature.

Although UVA boundary conditions have been developed for DSM2, due to time constraints UVA was not simulated in DSM2-QUAL. Instead, relationships between UVA and DOC were developed for each of the four urban intakes based on MWQI grab sample data.

The bromide concentration at Rock Slough was developed from regressions of (1) Contra Costa Canal Pumping Plant #1 chloride data to Contra Costa Canal Pumping Plant #1 data, and (2) Contra Costa Canal Pumping Plant #1 chloride data to Rock Slough EC. The bromide relationships used in for Rock Slough and for the remaining urban intake locations was developed based on Delta wide relationships are given in Chapter 2 of the December 2003 Draft Report on Water Quality.

The 16-year minimum, average, and maximum daily averaged TTHM concentration at the four urban intakes for study 1 (base case) and study 4b is shown below in Table 4.10. The TTHM concentration associated with the 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentile at each location is also shown. These percentiles were calculated in the same manner as the chloride percentiles. Although the 50^{th} percentile (median) TTHM concentrations for all locations are similar to the 16-year average concentrations, the 90^{th} percentile concentrations are much lower than the 16-year maximums.

Table 4.10: Summary of Daily Averaged TTHM (ug/L) at Urban Intakes

Urban Intake	Study	Min	Ave	Max	Percentiles 10th	25th	50th	75th	90th
RS	Study 1	18	37	88	25	29	35	43	52
	Study 4b	18	42	115	27	31	38	49	60
LVR	Study 1	17	36	77	25	29	35	42	50
	Study 4b	17	41	131	27	32	38	48	57
SWP	Study 1	19	35	63	25	29	35	40	47
	Study 4b	19	40	82	27	32	38	47	53
CVP	Study 1	17	37	102	26	30	37	43	49
	Study 4b	17	41	113	26	32	40	49	57

The 14-day average TTHM constraints called for by the Delta Wetlands WQMP were calculated every day as the average of the 14 previous days (WQMP, 2000). This was done not only to remain consistent with CALSIM, but also under the assumption that forecasting and operations would make use of the previous 14 days worth of field and modeling data. A summary of the 14-day average TTHM constraints is shown in Table 4.11.

Table 4.11: Summary of 14-Day Average TTHM (ug/L) at Urban Intakes

Urban Intake	Study	Min	Ave	Max	Percentiles				
					10th	25th	50th	75th	90th
RS	Study 1	19	37	85	26	29	35	43	51
	Study 4b	20	41	104	27	32	38	49	59
LVR	Study 1	20	36	73	25	29	35	42	50
	Study 4b	20	41	108	28	32	39	48	57
SWP	Study 1	20	35	61	26	29	35	40	47
	Study 4b	20	40	75	27	32	38	47	52
CVP	Study 1	18	37	89	26	30	37	43	49
	Study 4b	18	41	103	26	32	40	49	56

Violations of the Water Quality Management Plan (WQMP) TTHM standard are not based on the 14-day averages, but instead on the difference between the new In-Delta storage operation and the modeled base case. According to the WQMP, when the modeled base case TTHM is less than or equal to 64 ug/L, the modeled project (alternative) TTHM can not exceed 64 ug/L. When the base case TTHM already exceeds 64 ug/L, the 14-day average increase in TTHM concentration at any urban intake can not exceed 3.2 ug/L. The incremental WQMP constraint is illustrated below in Figure 4.10.

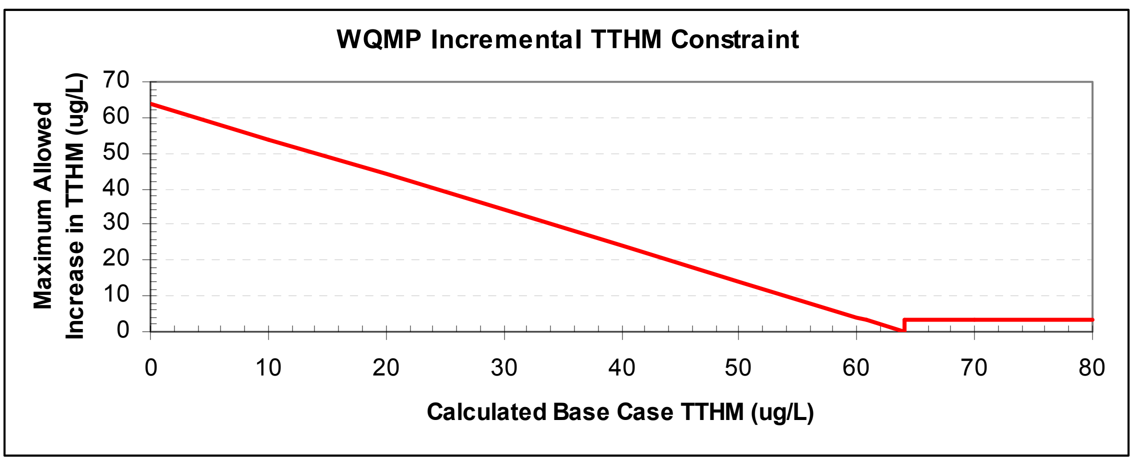


Figure 4.10: WQMP Incremental TTHM Constraint

The 16-year minimum, average, and maximum change (study 4b - study 1) in the 14-day average TTHM at the urban intakes is shown in Table 4.12. The 10th percentile results so a slight improvement (decrease) in TTHM concentrations, while the 25th percentile results show an equivalent increase in TTHM concentrations.

Table 4.12: Summary of Change in 14-Day TTHM (ug/L) at Urban Intakes

Urban Intake	Min	Ave	Max	Percentiles 10th	25th	50th	75th	90th
RS	-3.5	4.5	26.7	-0.4	0.3	2.9	7.1	12.1
LVR	-4.5	4.6	37.7	-0.5	0.5	3.2	7.1	12.0
SWP	-4.8	4.3	22.1	-0.2	0.4	3.0	6.9	11.0
CVP	-3.1	4.1	42.5	-0.1	0.1	2.6	6.5	10.9

4.5.5 Bromate at Urban Intakes

Like the other water quality constraints, the impact of bromate (TTHM) formation is measured by increases in the project alternative when compared to the modeled base case concentration. Like TTHM, bromate is not directly modeled in DSM2. The WQMP established an incremental standard (described below) and agreed upon the basic modeling approach to be used to calculate bromate. Bromate is calculated as a function of EC and DOC.

The 16-year minimum, average, and maximum daily averaged bromate concentration at the four urban intakes for study 1 (base case) and study 4b is shown below in Table 4.13. The bromate concentration associated with the 10th, 25th, 50th, 75th, and 90th percentile at each location is also shown.

Table 4.13: Summary of Daily Averaged Bromate (ug/L) at Urban Intakes

Urban Intake	Study	Min	Ave	Max	Percentiles 10th	25th	50th	75th	90th
RS	Study 1	0.1	5.7	14.3	2.3	3.0	5.2	7.9	10.0
	Study 4b	0.2	6.0	14.9	2.4	3.2	5.5	8.5	10.4
LVR	Study 1	0.2	7.3	18.9	2.4	3.5	6.8	10.3	13.0
	Study 4b	0.1	7.5	19.1	2.4	3.7	6.9	11.0	13.3
SWP	Study 1	0.1	6.9	17.4	2.4	3.7	6.5	9.7	11.8
	Study 4b	0.1	7.1	17.1	2.4	3.8	6.8	10.1	11.9
CVP	Study 1	0.1	7.9	18.4	2.4	5.3	8.0	10.6	12.6
	Study 4b	0.1	8.0	18.4	2.4	5.4	8.1	10.9	12.8

The 14-day average bromate constraints called for by the Delta Wetlands WQMP were calculated every day as the average of the 14 previous days. This was done not only to remain consistent with CALSIM, but also under the assumption that forecasting and operations would make use of the previous 14 days worth of field and modeling data. A summary of the 14-day average bromate constraints is shown in Table 4.14.

Table 4.14: Summary of 14-Day Average Bromate (ug/L) at Urban Intakes

Urban Intake	Study	Min	Ave	Max	Percentiles				
					10th	25th	50th	75th	90th
RS	Study 1	0.6	5.7	13.6	2.3	3.0	5.2	7.9	9.9
	Study 4b	0.7	6.0	14.6	2.4	3.2	5.5	8.5	10.2
LVR	Study 1	0.8	7.3	18.5	2.4	3.5	6.7	10.3	12.9
	Study 4b	0.6	7.5	18.1	2.4	3.8	6.9	11.0	13.2
SWP	Study 1	0.7	6.9	17.1	2.4	3.7	6.5	9.7	11.8
	Study 4b	0.7	7.1	16.8	2.4	3.8	6.8	10.1	11.9
CVP	Study 1	0.3	7.9	16.9	2.4	5.2	8.0	10.5	12.5
	Study 4b	0.3	8.0	17.5	2.4	5.4	8.1	10.9	12.7

The 16-year minimum, average, and maximum change (study 4b - study 1) in the 14-day average bromate at the urban intakes is shown in Table 4.15.

Table 4.15: Summary of Change in 14-Day Bromate (ug/L) at Urban Intakes

Urban Intake	Min	Ave	Max	Percentiles				
				10th	25th	50th	75th	90th
RS	-0.6	0.3	2.0	-0.1	0.0	0.2	0.5	0.9
LVR	-1.6	0.2	2.8	-0.4	-0.1	0.1	0.5	1.0
SWP	-1.7	0.2	2.5	-0.4	-0.1	0.1	0.4	0.8
CVP	-2.2	0.2	2.0	-0.3	-0.1	0.1	0.4	0.7

4.6 Conclusions and Recommendations of Modeling Studies

4.6.1 Conclusions

- In general, the DSM2-QUAL results representing 16-years of operations, not only reflect changes to Delta water quality due to operation of the project, but should be viewed as responding to larger system wide changes made within CALSIM II Model.

- The 10th, 25th, 50th, 75th, and 90th percentile states are provided for many of the flow and water quality parameters related to the operation of the In-Delta Storage Project. These percentile values can be used to fill in the general shape of the missing cumulative frequency distributions, and provide valuable insight into change in frequency of events.

- A general summary of the range (16-year min and max), median (50th percentile), and percent time that the WQMP constraints were exceeded (regardless of the magnitude of the difference) for all four urban intakes combined is shown in Table 4.16 for the following water quality parameters. The lowest and highest values for all four urban intakes are shown for each of these three statistics. The lowest and highest values frequently come from different locations.

Table 4.16: Summary of Change in Water Quality Constituents for all Urban Intakes

Water Quality Constituent	Range	Median	% Days > WQMP Standard
Chloride	-21.8 – 40.7 mg/L	0.1 – 0.4 mg/L	1 – 8%
DOC	-0.6 – 4.4 mg/L	0.3 – 0.5 mg/L	9 – 33%
TTHM	-4.8 – 42.5 ug/L	2.6 – 3.2 ug/L	3 – 6%
Bromate	-2.2 – 2.8 ug/L	0.1 – 0.2 ug/L	17% - 22%

- It is important to not focus on generalized statistics covering all of the locations for the entire simulation period, but rather to spend time reviewing the percentile results for both the change in water quality and absolute results for each individual location. However, though the range of values shows a highly varied response to the various water quality parameters, the median values show a very slight increase in all four water quality parameters covered in this study. The estimate of the percent days that the WQMP standards adopted in D1643 were exceeded does not take into account the magnitude of each exceedence of the standards. At times, the differences between D1643 compliance and a violation are minor. The time series plots for each water quality parameter provide a crude estimate of the magnitude of these differences.

4.6.2 Recommendations

Though the current study was designed to accommodate a fairly complete simulation of several of the key physical processes unique to the operation of the In-Delta Storage Project, the magnitudes and details associated with some of these processes are not completely understood. Often types of scaling or sensitivity analysis have been used to bookend or justify assumptions made when developing boundary conditions or mechanisms to represent these processes. In most cases, the DSM2 simulations were designed such that these assumptions can be easily repeated and/or tested in future studies. The following are suggestions for improvements to future DSM2 simulations:

- Either remove seepage flows if the reasoning for assigning a fixed concentration to the seepage return flows is insignificant or make use of the current DSM2 setup and conduct an actual sensitivity test on the seepage return flow concentrations;

- Estimate the long-term mass flux of the various water quality constituents passing through the urban intakes;

- Improve the project island volume – flow relationships used in the CALSIM II DOC constraints by rerunning the DSM2-QUAL fingerprinting simulation for conditions similar to the proposed circulation operations;

- Conduct and present a formal scale analysis of the project island volume – flow relationships;

- Develop and apply flow – organic carbon relationships for the flow boundaries;

- Develop and apply a daily ANN or other EC / chloride constraint in CALSIM II to better match the current DSM2 salinity simulations;

- Quantify the difference in organic carbon produced by the project islands in DSM2 to the amount of organic carbon produced in CALSIM II, and if the values are significantly different, rethink the way DSM2 is representing DOC in the project islands; and

- Extend the DSM2 analysis (post-processing) time frame such that cumulative frequency distributions and closer analysis between the CALSIM and DSM2 results may be conducted.

4.7 DO and Temperature Studies

Two DSM2 planning studies were run in HYDRO and QUAL with and without the proposed the In-Delta storage reservoirs in the SWP and CVP systems. The objective of the study was determine whether the In-Delta Storage Reservoir operations would meet the Dissolved Oxygen (DO) and temperature standards at the outlets or not. Both of the scenarios were simulated with the CALSIM II Daily Operations Model. A listing of the DSM2 / CALSIM II scenarios (Study 1 and Study 4b) used in DO and temperature analyses is given in Section 4.4. Detailed descriptions of the operation scenarios are given in Chapter 3 on Operations. The interaction between CALSIM II and DSM2 is illustrated in Figure 4.11.

4.7.1 Modeling Approach and Boundary Conditions

There is a close interaction between the DO and other water quality parameters. In particular, DO interacts with water temperature, BOD, chlorophyll, organic nitrogen, ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, organic phosphorus, and dissolved phosphorus (ortho-phosphate). In order to simulate DO, a group of related variables has to be simulated at the same time.

The interaction among water quality variables in DSM2 model is shown in Figure 4.12. In Figure 4.12, the rates of mass transfer are functions of temperature. It is important that the temperature simulation be included in the DO simulation. Further information on DSM2 kinetics is given in a 1998 report by the Department of Water Resources (Rajbhandari 1998), also available at the Delta Modeling Section web site http://modeling.water.ca.gov/delta/reports/annrpt/1998/chpt3.pdf.

The representation of project islands and the island release points as modeled in the DSM2 model is shown in Figure 4.13. Recent works on calibration and validation of DSM2 for DO are documented in Rajbhandari et al (2002). The conceptual and functional descriptions of constituent reactions represented in DSM2 are based generally on QUAL2E (Brown and Barnwell 1987), and Bowie et al. (1985). The DO concentration in the island reservoir is both a function of mixing associated with diversions to the islands, changes due to growth, decay and mass transformations, oxygen demand associated with the peat soils, wind effects, and stratification. DSM2 can be used to model all of the effects except for stratification.

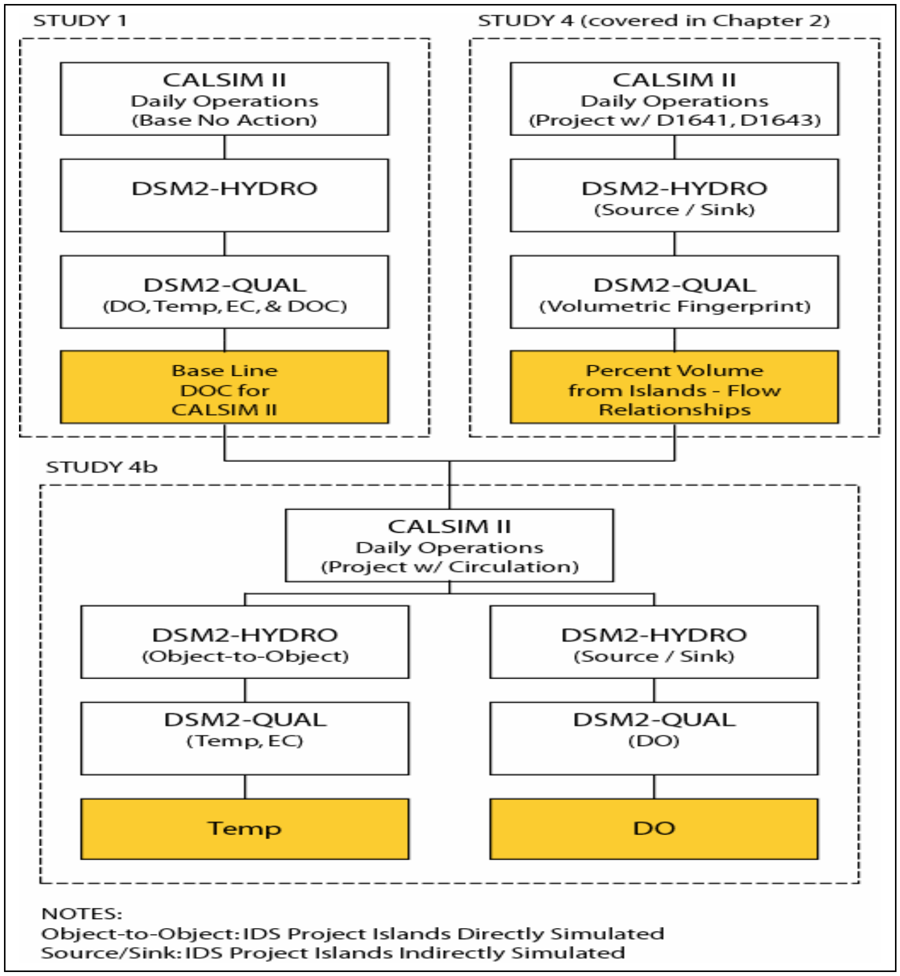


Figure 4.11: Study Methodology

Data collected at hourly intervals for DO and temperature provides boundary information needed by DSM2. Estimated DO data in Sacramento River at Freeport were provided for the Sacramento River model boundary. The historical record of DO and temperature, available from May 1993 at Martinez including estimates for missing data, was used for the downstream boundary. The estimates were based on extrapolations of 1997-2000 data, averaged to daily averages, and extended to 1975-1983. Since continuous data were not available at Vernalis (RSAN112), hourly values of DO and temperature available from the nearby station at Mossdale (RSAN087) were used to approximate these quantities for the boundary inflow at Vernalis. For 1975-1983, estimates based on extrapolation of data were used. Since the flows at Vernalis are primarily unidirectional, and the hydraulic residence time is relatively short, this assumption seems appropriate.

Nutrient data at Vernalis were approximated from the San Joaquin River TMDL measurements sampled at weekly intervals in 1999. The nutrient data at Freeport on the Sacramento River were approximated from the latest publication of the U.S. Geological Survey report (USGS 1997) and chlorophyll data were approximated from the statistical analysis study by Nieuwenhuyse, 2002. Estimates of flow and water quality of agricultural drainage returns at internal Delta locations were based on earlier DWR studies. Estimates of data were also based on other sources such as Jones and Stokes (1998).

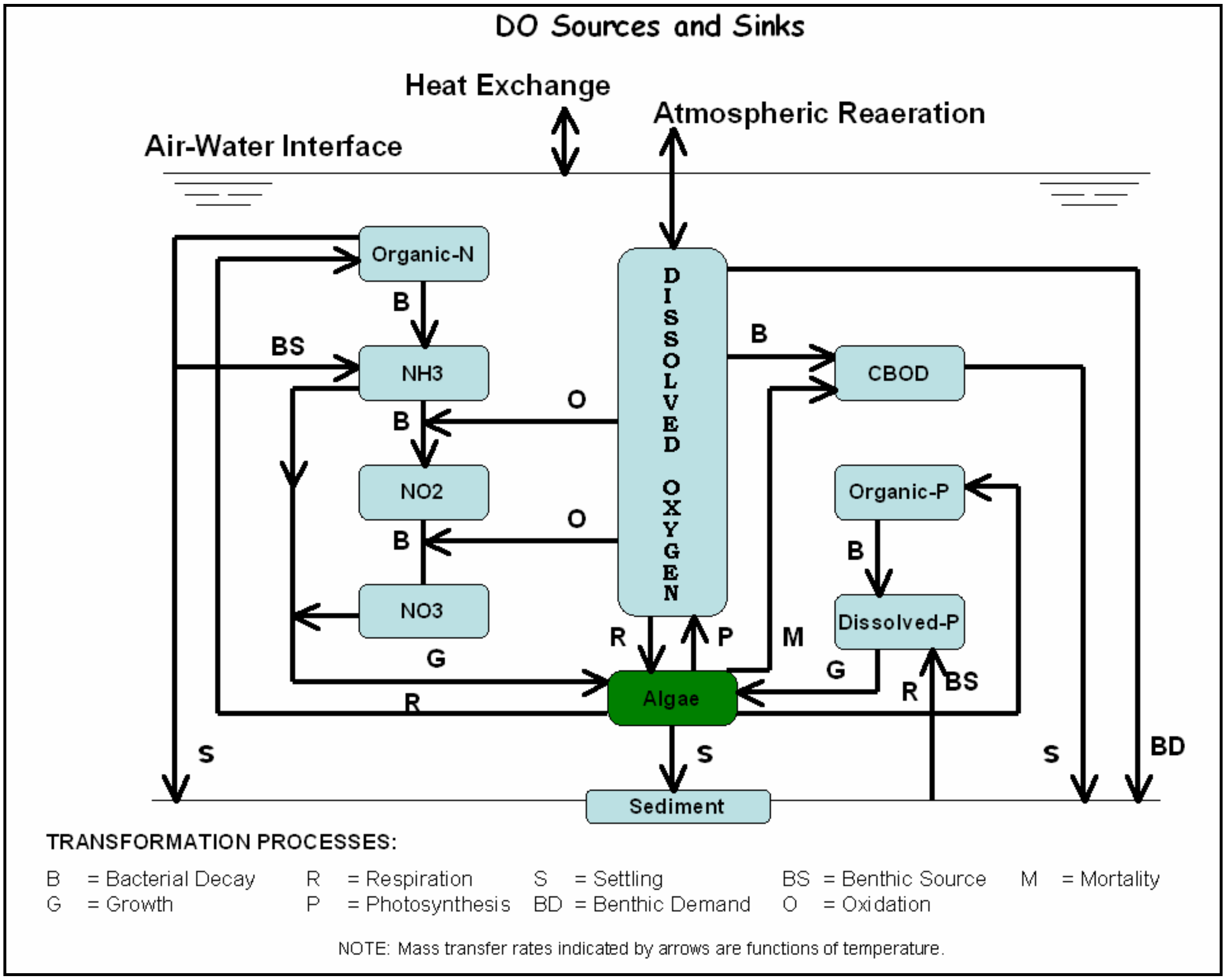


Figure 4.12: DO and Interaction among Water Quality Parameters

Climate data at hourly or 3-hour intervals representing air temperature, wetbulb temperature, wind speed, cloud cover, and atmospheric pressure (source: National Climatic Data Center) provided DSM2 input for simulation of water temperature. An electronic version of the data available for the period of 1997-2000 were extrapolated to cover the 16 years period from 1975-1991.

Model simulations were based on 15 minute time-steps. However, analysis of model results was based on daily averaged values because hydrodynamics information and water quality conditions were based on daily averaged values.

4.7.2 Project Island DO and Temperature

Temperature and DO were simulated using two different approaches (see Figure 4.12). Temperature was simulated using an object-to-object approach, where the In-Delta Storage Project islands were directly simulated. Water was diverted to or released from either island at one or two of its integrated facilities. The In-Delta Storage Project islands were simulated indirectly for DO by using a source / sink approach similar to the DSM2 treatment of the inflow / export boundary conditions. Time series were used to describe the concentrations to associate with releases from the islands. Since diversions were treated as sinks, the concentration of water diverted to the islands had no impact on the channels.

4.7.2.1 Temperature

Temperature inside of either island is both a function of mixing associated with diversions/releases to/from the islands, wind effects, heat exchange from atmosphere, and stratification. DSM2 modeled all the effects except for stratification. Therefore, the model results discussed below applies to cases where the stratification effects are negligible. One significant assumption is that DSM2 simulates reservoir as completely mixed.

4.7.3.1 Dissolved oxygen

The concentration of DO inside of either island is both a function of mixing associated with diversions/releases to/from the islands, changes due to growth, decay and mass transformations, oxygen demand associated with the peat soils, wind effects, and stratification. Because DSM2 has never been calibrated or validated for modeling DO in reservoirs, at this time it was not possible to simulate reservoir DO. More importantly there is no data for even attempting to calibrate DO in the project islands. As an alternative approach, preliminary assessment of reservoir release impact on channels was based on the source/sink approach described above. Based on the discussion among Water Quality Team members, the following water quality parameters were assigned for island release.

Three scenarios were chosen:

High chlorophyll	BOD 20-25 mg/l	Chlorophyll = 100 ug/l
Low chlorophyll	BOD 20-25 mg/l	Chlorophyll = 10 ug/l
Low BOD;Mid chlorophyll	BOD 8-10 mg/l	Chlorophyll = 40 ug/l

Other parameters were kept at the following values for all three scenarios.

Ammonia as nitrogen	0.05 mg/l
Nitrate as nitrogen	0.5 mg/l
Nitrite as nitrogen	~0.0
Organic nitrogen	2.0 mg/l
Dissolved ortho-phosphate	0.025 mg/l
Organic phosphorus	0.2 mg/l

Because discharge of stored water is prohibited if the DO of stored water is less than 6.0 mg/L, it was assumed that DO of island water would be at 6 mg/l at all times. In reality, this may require some aeration or application of other DO improvement technology which is beyond the scope of this study. EC (daily varying) input for release was used from the simulations by Mierzwa (2003). Temperature input (daily varying) was used from the simulations described in Section 4.9.

The difference in DO between the high chlorophyll and low chlorophyll scenarios typically was less than or equal to 0.4 mg/L. Though the DO results for the low chlorophyll scenario are somewhat better than those from the high chlorophyll scenario, a 0.4 mg/L difference is small enough that a time series plot of the low chlorophyll results would look similar to the high chlorophyll results. Furthermore, due to modeling and analysis time constraints, only the high chlorophyll and intermediate (low BOD, middle range chlorophyll) scenarios are plotted and discussed below.

4.8 DO and Temperature Requirements

The following DO and temperature constraints were utilized in evaluating the studies:

DO: Discharge of stored water is prohibited if the DO of stored water is less than 6.0 mg/L, if discharges cause the level of DO in the adjacent Delta channel to be depressed to less than 5.0 mg/L, or if discharges depresses the DO in the San Joaquin River between Turner Cut and Stockton to less than 6.0 mg/L September through November.

Temperature: Discharge of stored water is also prohibited if,

- The temperature differential between the discharged water and receiving water is greater than 20º F, or
- If discharges will cause an increase in the temperature of channel water by more than:
    - 4º F when the temperature of channel water ranges from 55º F to 66º F,
    - 2º F when the temperature of channel water ranges from 66º F to 77º F, or
    - 1º F when the temperature of channel water is 77º F or higher

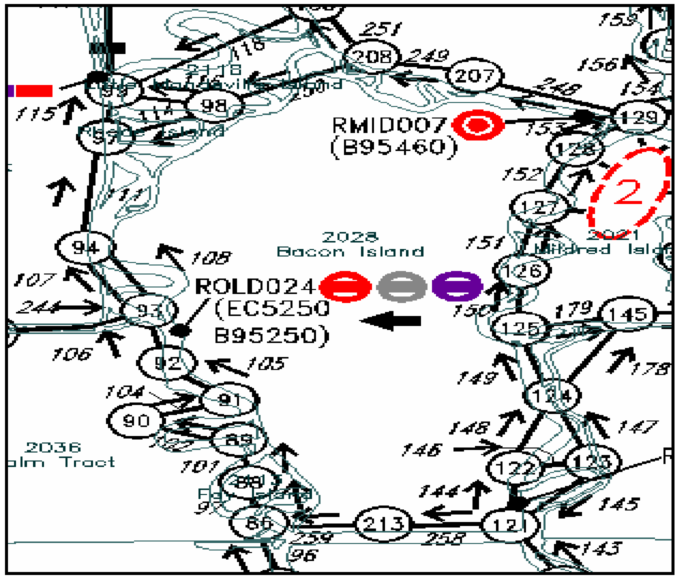
4.8.1 Output Location

To examine the impacts of project reservoirs on the channel DO and temperature, DSM2 output were requested for two locations. The first output was requested for the DSM2 Node 40 (Figure 4.13). This location is close from the Webb Tract San Joaquin intake structure of the In-Delta Storage reservoir. The second output location was Node 128, which is close to the release point from the bacon island.

4.9 Simulation Results

4.9.1 DO near the Islands

High Chlorophyll Scenario
This scenario considers island release at high BOD and high chlorophyll levels. The bar plot of the differences in the channel DO with and without project is shown in Figure 4.14. Time variations plots for the DO near project islands are shown in Chapter 4 of the December 2003 Draft Report on Water Quality. For the sake of clarity, the 16 year simulation time series plots are broken into four plots covering equal time period. For most times, the DO with the project is above 6 mg/l. For the



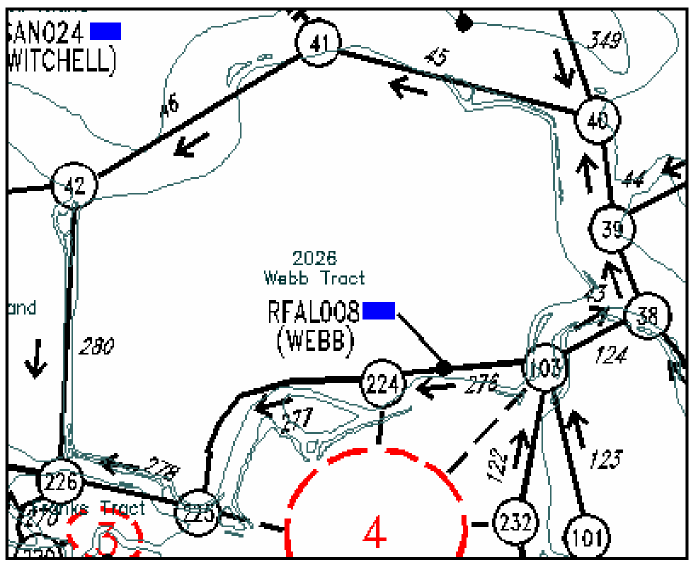


Figure 4.13: Representation of Webb Tract and Bacon Islands in DSM2

Webb Tract the DO remains always above 6 mg/l. For Bacon Island the DO goes below 6 mg/l, however for about 15 days for 16 years simulation period. For the planned project operations, the variations of DO in the channels with and without project follow similar trend.

For both scenarios, channel DO is higher during winter months and lower during summer months because of higher DO saturation values at lower temperatures. Among the two output locations, Bacon Island intake (Node 128) has lower DO than Webb Tract (Node 40) intake. Although the operation lowers the channel DO, the plots show no violation of channel DO since the DO is never depressed to below 5 mg/l. The minimum DO seems to occur near Bacon Island intake during March 1988. In general, the DO values decrease with the project operations. However, the change is lower than the one that would cause DO to be less than permissible value of 5mg/l. Among the two locations, the change in DO (with and without project) is more in Bacon Island which may be attributed to lesser amount of mixing near the intake structure.

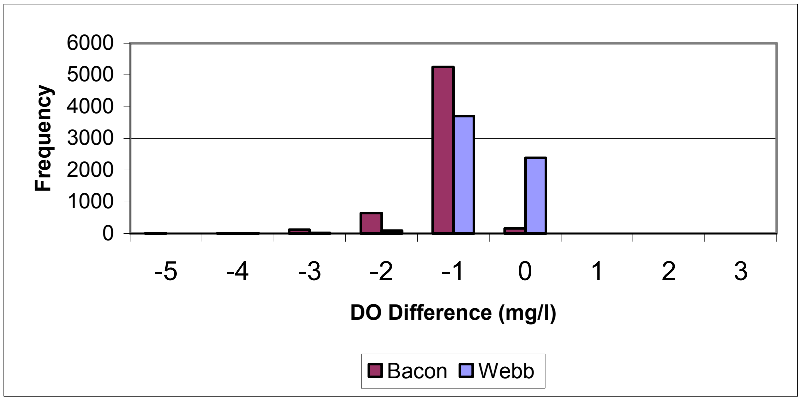


Figure 4.14: Bar Plot of Channel DO Differences with and without Project (High chlorophyll)

Intermediate Scenario

This scenario considers island release at low BOD and middle range of chlorophyll levels. The daily average difference in DO (high DO - intermediate DO) on the Middle River near the Bacon Island release point is shown in Figure 4.15, along with the actual daily average DO for the high and intermediate scenarios. The sensitivity of DO to the different chlorophyll and BOD as measured by the difference between the two scenarios ranged between 0.05 to -2.05 mg/L. DO plots near the project island integrated facilities (i.e. release points) is shown for Bacon Island in Figures in Chapter 4 of the December 2003 Draft Report on Water Quality. Compared to the high chlorophyll scenario, the impact on channel DO due to project releases (Fig 4.16) is smaller.

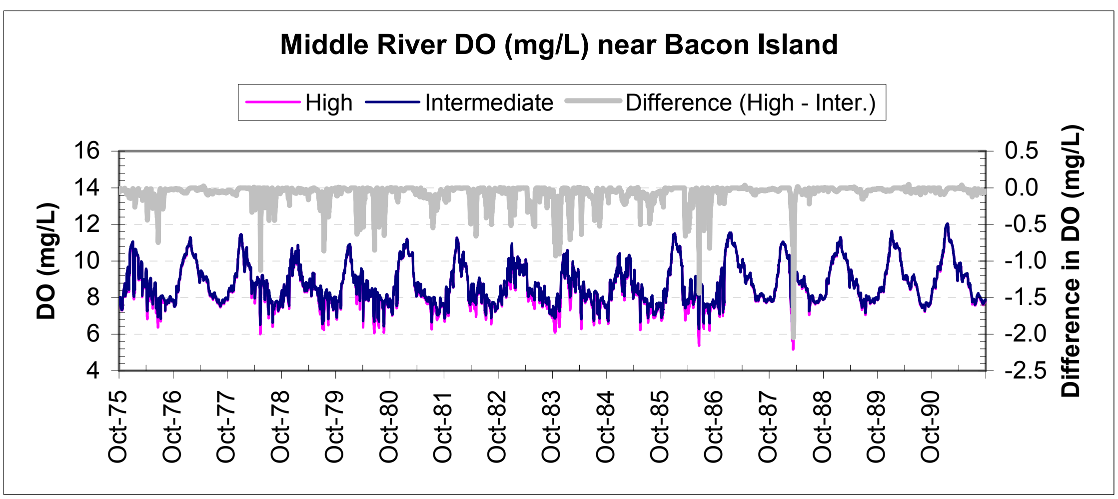


Figure 4.15: Sensitivity of DO for High and Intermediate Chlorophyll Scenarios

4.9.2 Temperature near the Islands

For both scenarios, the channel temperatures follow similar seasonal pattern. Under the revised operation rules, violations in the channel water temperature are minimal. For a total of 16 years simulation period, the violation occurred for about 5 and 2 days for Bacons Island and Webb Tract, respectively. As summarized in Table 4.17, these violations only occur during summer times when one degree or lower temperature differential requirement applies. Considering the simulation period of 16 years, this can be attributed to inherent noise within the model. Channel water temperature for base and project operation scenarios are plotted in figures in Chapter 4 of the December 2003 Draft Report on Water Quality.

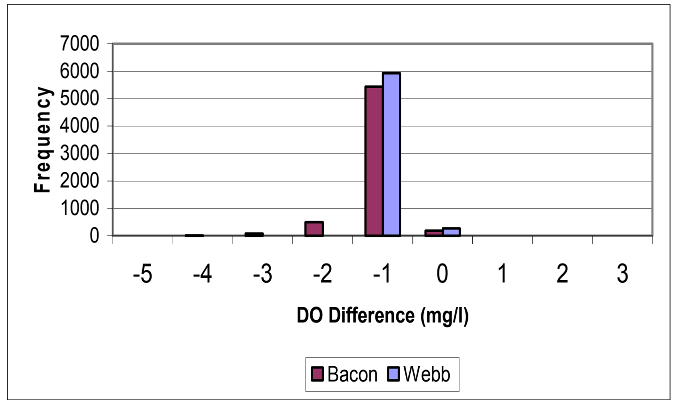


Figure 4.16: Bar Plot of Channel DO Differences with and without Project (Intermediate)

Table 4.17: Summary of Violation Period in Water Temperature

Release Island	Channel Temperature (^{0}F)	Violation (^{0}F)	Time Period
Bacon	t>77	>1	June 15-16, 1976
Bacon	t>77	>1	July 11-12, 1979
Bacon	66<t<77	>2	June 14, 1976
Webb Tract	t>77	>1	June 12-13, 1976
Webb Tract	66<t<77	>2	None

4.10 Conclusions and Recommendations of DO and Temperature Studies

4.10.1 Conclusions

- DSM2 modeling indicates that for the set of island water quality parameters used in this study, proposed In-Delta Storage Project operation will not violate the DO condition in the channel assuming that the DO (and not other parameters) associated with releases meets the WQMP DO objectives. Under the planned operation rules, the island DO level was set at 6 mg/l. If this required criterion for island DO is not met, or changed, the study conclusions will not be valid.
- For the chosen scenarios of high chlorophyll, low chlorophyll, and intermediate organic load in the island release, no violation was indicated in the channel DO differentials with and

without project islands. Due to lack of data, the assumed parameters may not include all the variations that could occur through complex interaction of plants and peat soil in the islands.

- A few days violations could occur for the temperatures that are higher than 77 degrees.
- Model simulation did not indicate that differences in water temperature between the island and the channel would exceed 20^0 F.
- DSM2 assumes that the reservoir is fully mixed and there is no stratification. Therefore, the model results will not be valid when sufficient stratification occurs.

4.10.2 Recommendations

- Water quality data needed for boundary conditions for the planning study were based on extrapolation of available data, when historical data were not available. Inclusion of more observed data is likely to improve the study analysis.
- A detailed investigation of island dynamics should be conducted to result in more confidence in the water quality of reservoir release. It may require further mesocosm studies, and calibration and validation of a reservoir model.
- Because of the inherent complexity of the reservoir dynamics, more time should be given for DSM2 analysis and post-processing so that sensitivity analysis could be conducted.

4.11 Reservoir Stratification Studies

DYRESM is a private domain (Flow Science Inc.) water quality model developed for 1D, 2D and 3D hydrodynamic evaluations. This model was originally applied for salinity evaluations in the Delta and during the State Feasibility phase and its use has been extended to ID applications for reservoir stratification studies. DYRESM modeling of stratification in the island reservoirs were conducted for three representative years. The following work was performed by Flow Science Inc. to further evaluate likely reservoir water temperatures and the possibility of stratification.

- Develop meteorological data sets for the reservoir islands.
- Determine if the reservoir islands will stratify using the one-dimensional DYRESM model.
- Quantify likely water temperatures for the reservoir islands and discuss potential changes in channel temperature resulting from reservoir discharge.

Further details on the stratification analysis are provided in the DWR Draft Report on Water Quality. CALSIM II and DSM2 circulation Study results were provided as input to the DYRESM model to check stratification in reservoirs. Results from the DYRESM show that:

- there are three primary criteria: mixing energy associated with inflow and outflow, stratification and temperature and salinity gradients mixing;
- short lived thermal stratification is more likely to occur at lower wind speeds, on the order of 2 m/s;
- stratification in the DYRESM simulations was weak and short lived; and
- reservoir water temperature in the summer when most discharges will occur were generally in the range of 70^0 to 90^0 F.

Chapter 5: ENGINEERING INVESTIGATIONS

5.1 General

One of the main issues to be resolved for the In-Delta Storage Project is to ensure that the engineering designs of the reservoir embankments and integrated facilities are technically feasible and can be implemented at an acceptable level of risk with justifiable cost.

The engineering investigations undertaken to reach a feasibility decision are interlinked, and the information flows from one investigation into another as shown in Figure 5.1. The investigations were separated into four areas: field investigations, engineering design and analyses, construction methods and cost estimation, and risk analysis.

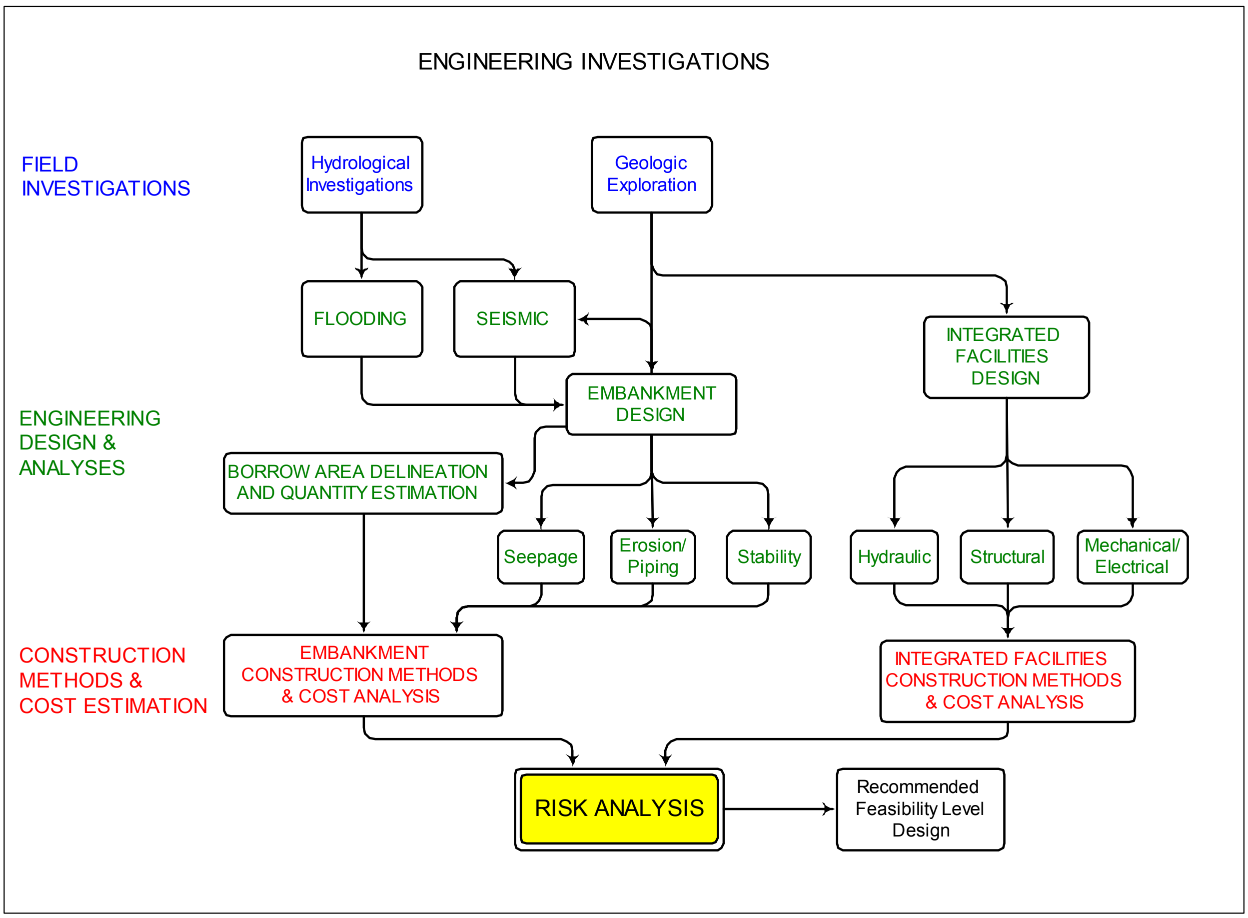


Figure 5.1: Engineering Investigations Flow Chart

Summary information on design criteria and considerations, analysis procedures and results of investigations, and construction methods and costs, are presented in this section. Further information on field investigations, basis of engineering analyses, and construction methods and cost estimating techniques for embankments and integrated facilities is presented in the DWR Draft

Engineering Investigations Summary report, June 2003. Details of the engineering investigations for each area shown in Figure 5.1 are also given in individual reports listed under Detailed Study Reports on Page xi.

5.2 Field Investigations

5.2.1 Hydrological Investigations

The hydrological investigations included a literature review of historical flood events and wind velocities and a tidal analysis of river stages.

As part of the flooding analysis, historical data including flood and tide elevations in the Delta region were obtained from previous studies conducted by CALFED, DWR, U.S. Army Corps of Engineers (USACE) and URS.

The tidal analysis included conducting detailed statistical analyses of the available stage data to obtain historical distributions of the tidal stages near the integrated facility locations. This information was required for the design of integrated facility components such as fish screens, diversion and release structures, and pumping plants.

Wind velocities for the “fastest mile of record” were obtained from generalized charts published by USACE (1976) and USBR (1981). The “fastest mile of record” was used to calculate average wind velocities associated with the minimum wind duration required to generate the reservoir wind wave spectrum. The estimated “fastest mile of record” wind velocities at the reservoir sites for winter, spring, summer and fall are 60, 56, 40, and 60 miles per hour, respectively.

5.2.2 Geologic Explorations

Geologic explorations were conducted to determine the soil properties of potential borrow sources on the reservoir islands and to evaluate the integrated facility foundation materials. The geologic data obtained from these explorations were used in the embankment design, borrow area investigations and integrated facilities structural design.

The geologic explorations were conducted in two phases. In the first phase, conducted during August and September 2002, USBR performed Cone Penetrometer Test (CPT) borings ranging from 28 to 101 feet in depth. CPT soundings of 28 to 52 feet in depth were used for the characterization of borrow areas and materials on both islands, while 85 to 101 foot deep soundings were used determine foundation conditions beneath the proposed integrated facilities. The second phase, conducted by DWR during September and October 2002, consisted of drilling and sampling one 100-foot drill hole at each of the four integrated facility sites. These drill holes were used to determine foundation conditions beneath the proposed integrated facilities. URS conducted additional explorations as a part of their borrow area investigations on Webb Tract and Bacon Island in December 2002. This included 20 drill holes (10 per island) ranging in depth from 15 to 19 feet below the existing ground surface.

The CPT and bore-hole logs were then compiled and used to develop geologic cross sections and isopach maps showing the thickness of soft and/or organic soils overlying potential borrow materials. Laboratory testing was then conducted on samples from the integrated facility locations by DWR's Division of Engineering, Civil Engineering Branch. The URS exploratory boring samples were tested to evaluate their engineering properties for use in borrow material evaluations.

The CPT logs and the laboratory testing data are presented in the following In-Delta Storage Program draft reports completed by DWR in January 2003: 1) Results of Geologic Exploration Program, and 2) Results of Laboratory Testing Program.

5.3 Engineering Design and Analyses

Engineering design and analyses conducted for this feasibility study included flooding and seismic analyses, embankment design, integrated facilities design, and borrow area delineation and quantity estimation. The results from these investigations were used in the construction methods and cost estimation work and in the risk analysis.

5.3.1 Flooding Analysis

The purpose of the flooding analysis was to address the vulnerability and reliability of the existing conditions and In-Delta Storage re-engineered project under flood events. Freeboard requirements at Webb Tract and Bacon Island reservoirs were evaluated based on design flood stages and wind wave characteristics estimated for the Sacramento-San Joaquin Delta region. Using this information, embankment crest elevations of the reservoir islands were designed to protect the embankments from overtopping due to extreme flooding and wind loading conditions on the surrounding water bodies.

For the freeboard criteria, the embankment crest elevations shall be the larger of the following two criteria (CALFED, 2002):

- The maximum reservoir water storage elevation (+4 feet MSL) plus the wind wave runup plus setup on the reservoir. If wind wave runup plus setup is less than 3 feet, then a freeboard of 3 feet should instead be added to the maximum water storage elevation, or
- The water surface elevation of the design flood event on the slough side plus the wind wave runup plus setup. If the wind wave runup plus setup is less than 3 feet, then a freeboard of 3 feet should instead be added to the water surface elevation of the design flood event.

The wind and wave runup analysis results indicate that the maximum wind wave runup plus setup is 1.8 feet for Webb Tract and 1.4 feet for Bacon Island; therefore, the freeboard required for the embankments around both Webb Tract and Bacon Island is 3 feet on the design flood event. Adding the 3 feet of required freeboard to the 100-year flood levels at Webb Tract and Bacon Island, results in embankments having crest elevations of +10.1 feet at Webb Tract and +10.3 feet at Bacon Island. These crest elevations are also sufficient to prevent overtopping due to the 300-year flood event. The wave runup plus setup values on the reservoir sides were estimated to be 2.0 feet and 2.2 feet for Webb Tract and Bacon Island, respectively. Therefore, with maximum reservoir water storage at elevation +4.0 feet, both reservoir islands would have sufficient freeboard.

Breach analysis was performed assuming the sloughs surrounding Webb Tract and Bacon Island are categorized into three groups: narrow, medium, and wide. The objective of this breach analysis was to provide sufficient input to estimate the impacted areas and to quantify the consequences of failure from an uncontrolled release. Estimates for the probability of the re-engineered project embankments overtopping were completed as a part of the risk analysis.

Detailed information on the flooding analysis is provided in the URS Flooding Analysis, Draft Report April 2003.

5.3.2 Embankment Design

Under the embankment design analysis, analysis parameters were established and the vulnerability and reliability of the existing conditions and In-Delta Storage re-engineered project embankments were evaluated under operational demands by conducting extensive seepage and stability analyses.

Both the rock berm and bench options were included in the recommended design. The more expensive Bench Option would be used in areas where the slough is deep, the embankment slope on the slough is currently too steep to adequately place rock, or where the placement of rock may block a portion of the channel.

5.3.2.1 Analysis Parameter

Analysis parameters used in the seepage and stability analyses were established to define existing subsurface conditions, embankment geometry, material properties, and reservoir and slough water levels to be used.

The islands were divided into sections based on the elevation of the base of peat, and for the current study two sections were selected to be representative of the lowest (-40 feet) and highest (-20 feet) elevations at which the base of the underlying peat layer is found in the two islands. The configuration for the re-engineered embankments around both islands has an average crest elevation of +10 feet, with a final crest width of 35 feet. The inside slope of the reservoir above elevation +4 feet is 3H:1V and the lower slope is 10H:1V. Riprap protection covers the inside slope from elevation +3 to the crest. Two configurations were considered for the slough side slope. These are referred to as the “rock berm” option and the “bench” option (Figure 5.2). The “rock berm” option consists of constructing the new embankment on top of the existing levee. Where required to meet stability criteria, rock fill would be placed from the outboard crest of the existing levee outward to the bottom of the slough. The “bench” option consists of a bench, created by removing a portion of the existing levee to an elevation varying between 0 and 6 feet and constructing the new embankment from the reservoir side of the bench at a slope of 3H:1V to the crest of the embankment. Erosion protection for the slough side slope would consist of riprap and bedding.

5.3.2.2 Erosion, Piping and Seepage Analysis

Three potential problems erosion, piping and seepage could cause instability of the proposed embankments. Erosion of slopes could occur due to wave action. Movement of water through embankment materials due to difference in hydrostatic head may result in seepage of water either from the channel to the reservoir or from the reservoir to the channel. Piping is advanced stage of seepage where embankment materials in the seepage path start moving due to higher seepage rate and thus continuous flow paths are established in the embankment.

Steady-state seepage conditions through transverse sections of the existing levees and re-engineered embankments at Webb Tract and Bacon Island were estimated. Three sections were considered for the seepage analysis, representing narrow (400 feet), average (700 feet) and wide (1,200 feet) slough widths. In addition, two of these sections were evaluated assuming the sand is exposed in the island interior. For each section, three seepage conditions were evaluated: (1) existing conditions, (2) full reservoir with no pumping at the interceptor wells, and (3) full reservoir with required pumping at the interceptor wells to re-establish pre-reservoir seepage conditions at the levee across the slough at the adjacent island. A variety of seepage control alternatives were evaluated and a recommendation was made to use seepage pumps for seepage control.

To meet the USBR risk analysis requirements the potential for erosion and piping had to be addressed. The probability of erosion and piping failures was determined and six alternatives were considered as solutions to reduce the chance for erosion and piping to occur. On the basis of factors that can contribute to erosion and piping, areas requiring control were identified. After an evaluation of piping protection measures was performed based on effectiveness, constructibility and cost, geotextile filter fabric was selected as a preferred alternative.

The DWR Independent Board of Consultants recommended some level of reservoir side (inboard) erosion protection, either over large areas or over selected areas of special importance or vulnerability. Prevailing and storm winds are the key forces driving both wind and wave erosion potential, and an analysis of the wind direction in the area indicated south easterly winds dominate the islands area. Rip rap and soil cement were considered as alternatives for 10:1 slope protection. Based on cost in comparison to rip rap, soil cement with bentonite mix is proposed on the reservoir side north and west facing 10:1 slopes for protection against wind and wave action. Recently (Year 2002), the same type of slope protection has been provided for Clifton Court Forebay. As recommended by the DWR Independent Board of Consultants, filter fabric lining was provided on the interface between the existing levee and the new embankment and also on the reservoir side of the new embankment as shown in Figure 5.2. Slopes steeper than 10:1 were protected with rip rap protection on all sides of the reservoirs.

5.3.2.3 Stability Analysis

The rock berm and bench embankment options have been evaluated by extensive stability analyses of the two sections selected to be representative of the lowest and highest elevations at which the base of the underlying peat layer is found in the two islands (see Section 5.3.2.1). Conditions evaluated in the stability analysis include end-of construction, long-term operation, sudden drawdown, and pseudo-static. Factors of safety were calculated and compared to the project's stability criteria, and the adequacy of the proposed project in regard to embankment stability was evaluated. Stability analysis results for the rock berm option, which covers most of the embankment alignment, are given in Tables 5.1 and 5.2.

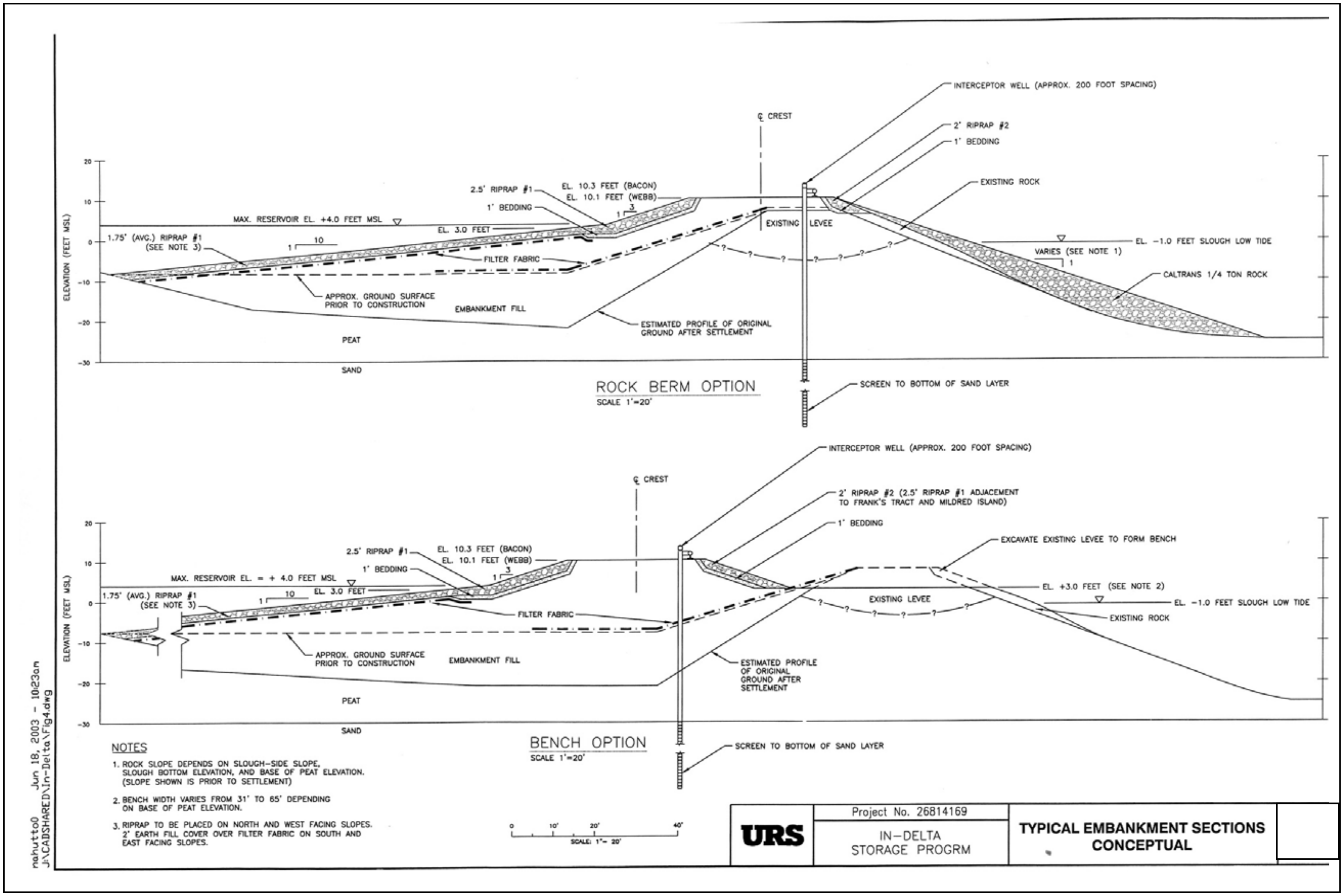


Figure 5.2: Conceptual Details for Typical Embankment

Table 5.1: Stability Analysis Results, "Rock Berm" Option [1] (Base of Peat at El. –20 feet)

Existing Slough Side Slope	Rock Berm Slope	Condition	Water Elevation		Side Slope Considered	F.S.	Ky
			Slough	Reservoir			
1.4H : 1V (worst)	none	long term	-1.0	4.0	Slough	0.9	--
	3H : 1V	long term	-1.0	4.0	Slough	2.4	--
2.6H : 1V (average)	none	long term	-1.0	4.0	Slough	1.1	--
	3H : 1V	long term	-1.0	4.0	Slough	2.0	--
		long term	7.0	empty	Reservoir	1.9	--
		sudden drwdn	6.0	4.0/empty	Reservoir	1.6	--
2.6H : 1V w/o liquefiable sand layer	3H : 1V	seismic	-1.0	4.0	Reservoir	2.8 [2]	0.14
		seismic	-1.0	4.0	Slough	2.7 [2]	0.25
		seismic	3.5	Empty	Reservoir	2.1 [2]	0.14
		seismic	3.5	Empty	Slough	3.0 [2]	0.27
2.6H : 1V w/ liquefiable sand layer	3H : 1V	seismic	-1.0	4.0	Reservoir	1.8 [2]	0.07
		seismic	-1.0	4.0	Slough	1.6 [2]	0.08
		seismic	3.5	Empty	Reservoir	1.3 [2]	0.03
		seismic	3.5	Empty	Slough	2.0 [2]	0.12
5H : 1V	none	long term	-1.0	4.0	Slough	1.4	--
(best) [3]	2' layer rock fill	long term	-1.0	4.0	Slough	1.8	--

[1] slough bottom = -25 feet.
[2] post-seismic factor of safety
[3] slough bottom = -20 feet

Table 5.2: Stability Analysis Results, "Rock Berm" Option [1] (Base of Peat at El. –40 feet)

Existing Slough Side Slope	Rock Berm Slope	Condition	Water Elevation		Side Slope Considered	F.S.	Ky
			Slough	Reservoir			
2.35H : 1V (worst)	none	long term	-1.0	4.0	Slough	1.1	--
	3H : 1V	long term	-1.0	4.0	Slough	1.8	--
2.6H : 1V (average)	none	long term	-1.0	4.0	Slough	1.2	--
	3.5H : 1V	long term	-1.0	4.0	Slough	1.8	--
		long term	7.0	empty	Reservoir	1.2	--
		long term	7.0	empty	Reservoir [2]	1.7	--
		sudden drwdn	6.0	4.0/empty	Reservoir [2]	1.5	--
2.6H : 1V w/o liquefiable sand layer	3.5H : 1V	seismic	-1.0	4.0	Reservoir [2]	2.6 [3]	0.09
		seismic	-1.0	4.0	Slough	1.9 [3]	0.11
		seismic	3.5	Empty	Reservoir [2]	2.0 [3]	0.09
		seismic	3.5	Empty	Slough	2.3 [3]	0.12
2.6H : 1V w/ liquefiable sand layer	3.5H : 1V	seismic	-1.0	4.0	Reservoir [2]	2.4 [3]	0.06
		seismic	-1.0	4.0	Slough	1.4 [3]	0.04
		seismic	3.5	Empty	Reservoir [2]	1.4 [3]	0.04
		seismic	3.5	Empty	Slough	1.8 [3]	0.07
3.5H : 1V (best)	none	long term	-1.0	4.0	Slough	1.3	--
	4H : 1V	long term	-1.0	4.0	Slough	1.6	--

[1] slough bottom = -30 feet.
[2] with u/s 2 foot thick horizontal rock berm
[3] post-seismic factor of safety

Details on the Embankment design are given in the URS Embankment Design Analysis, Draft Report June 2003.

5.3.3 Seismic Analysis

For the seismic analysis, dynamic response analyses of the embankments were performed to calculate time histories of seismic-induced inertial forces acting on the critical sliding masses. Seismic-induced permanent deformations of the embankments were estimated for the three ground motion levels selected for this study. The estimated deformations and their associated ground motion levels were used to evaluate the seismic risk of the proposed embankment alternatives and the probabilities of failure were estimated.

Site-specific estimates of ground motions for future earthquake occurrences were developed and earthquake acceleration time histories were spectrally matched to the selected ground motion response spectra. Dynamic response analyses of the embankments were then performed to calculate time histories of seismic-induced inertial forces acting on the critical sliding masses.

Review of the soil data indicates that there are some sections under the existing perimeter levees where the upper 5 feet of the underlying sand deposits may liquefy during a major 475-year or larger earthquake event. In addition, part of the existing levee on the island side may contain loose sands, which have the potential to liquefy when they become saturated during the reservoir filling. One consequence of the loose saturated sand liquefying is the reduction in shear resistance along the critical slip surface during earthquake shaking. In the context of this analysis, this translates into lower yield acceleration, which in turn induces larger deformations. Dynamic analyses for both cases involving non-liquefied and liquefied sandy layers were performed and embankment deformations for these cases were estimated.

The calculated seismic deformations are large under several conditions for the 475-year earthquake event. The results of the evaluation suggest that the rock berm option has a lower probability of failure than the bench option. The rock berm option is preferable to the bench option because it places the embankment over the existing levee, making use of the stronger peat under the levee (undrained shear strength 450 lb/ft^2), as opposed to the weaker free-field peat (undrained shear strength 200 lb/ft^2) that underlies the bench option. In addition, the rock berm alternative provides a more stable slough side slope.

The current designs do not provide for assured non-failure of the proposed storage facilities during strong seismic loading. Instead, the risk of failures (or breaches) of the proposed reservoirs are considered in the current planning and design as an acceptable level of risk. Such breaches would be significantly less costly to repair than typical failures of “existing” Delta levees, as embankment widths are greater and differential water elevations between the reservoirs and adjacent sloughs are greatly reduced during periods of reservoir storage. Also important is the reduction of the consequences of potential failures during low flow periods in the sloughs (Summer and Fall). During these periods the reservoirs would be full or at least partially full, so that potential failures would not result in drawing water into the failed reservoir islands, resulting in increased salinity levels. Instead, fresh water would be released, having a beneficial impact on salinity levels into what could otherwise be a damaged overall Delta system. Scour damage would also be minimized, facilitating rapid repair of potential failures on the two reservoir islands.

These are potentially very significant project benefits, but their value is difficult to assess and depends to some extent on the actions that may be taken to reduce seismic vulnerability of appurtenant islands, levees, and other Delta facilities.

Details on the Seismic Analysis are presented in the URS Seismic Analysis, Draft Report April 2003. This input is combined in the risk analysis for the probabilities of failure from various events (seismic, operational and flood) and their failure consequences and details are included in the URS Risk Analysis, Draft Report June 2003.

5.4 Borrow Area Delineation and Quantity Estimation

This investigation included identifying feasible borrow sites within Webb Tract and Bacon Island, assessing the suitability of the soils as borrow materials for earthwork, estimating the volume of borrow materials available from each identified location, and comparing the total quantity of suitable borrow material available at each island with the earthwork planned at the island. For the purpose of this study a "feasible borrow site" was defined as a site where the top surface of geotechnically-acceptable borrow soil deposits occurs within a depth of 15 feet below existing ground surface and where dewatering requirements during borrow excavations are expected to be low. However, later investigations of construction methods indicated that borrow materials can be extracted without dewatering by using dragline equipment currently available and being used for similar operations.

Information on available borrow materials from previous studies was reviewed. The investigations described in the following sections were conducted to determine the availability and suitability of borrow materials.

5.4.1 Field Exploration

A field exploration program was conducted for this study and included a field reconnaissance and geotechnical exploratory borings and sampling.

A geotechnical and environmental field reconnaissance on Webb Tract and Bacon Island was conducted during December 5 and 6, 2002, to identify the borehole locations and to examine a 50-foot radius circle around each drilling site for potential burrows or surface cracks. The drilling locations were adjusted to maintain a 50-foot radius clear of burrows or surface cracks and were located on disturbed areas, either on or adjacent to farm roads or within active agricultural fields.

Ten exploratory borings were drilled on each island during December 11 and 12, 2002. These borings totaled 165 linear feet and ranged in depth from 15 to 19 feet below the existing ground surface. The borings are designated W-1 to W-10 for Webb Tract and B-1 to B-10 for Bacon Island and are shown on Figure 2 (Webb Tract) and Figure 3 (Bacon Island).

A URS engineer logged the soil cuttings and samples in the field and visually classified the soils as the drilling proceeded. Samples of the subsurface materials were obtained at selected depths in the borings using a Standard Penetration Test (SPT) split-spoon sampler. Soil samples were also collected of the potential borrow materials that were visually classified as sand, silty sand (SM), clayey sand, sandy clay, or sandy silt.

5.4.2 Laboratory Testing

Laboratory testing was conducted on selected soil samples obtained from the exploratory borings to evaluate their engineering properties for use in borrow material evaluations. Laboratory tests were performed on the selected soil samples for grain size analyses, water content determination and Atterberg limits determination. Logs of borings were prepared based on the field logs, the visual examination in the laboratory, and the laboratory testing results.

5.4.3 Subsurface Conditions

On both islands, there is a highly organic soil and peat layer that ranges from a few feet to more than 15-feet thick. On Webb Tract, this layer is underlain by gray, silty sand (SM and SP-SM) that extends to the depth explored. This material varies in consistency from loose to medium dense and contains interbedded thin layers of gray sandy silt. On Bacon Island, the organic soil and peat layer is underlain by a gray, silty sand layer that extends to the depth explored. This material varies in consistency from loose to medium dense and contains interbedded thin layers of gray silty clay. The silt and clay contents and the water contents of the materials encountered in Bacon Island are higher than for the materials encountered in Webb Tract.

The level of groundwater encountered in the Webb Tract borings at the time of drilling varied from about 2 feet to 9 feet below the ground surface with most levels around 2 feet to 5 feet below the ground surface. The level of groundwater encountered in the Bacon Island borings at the time of drilling varied from about 3 feet to 13 feet below the ground surface, suggesting that the groundwater levels in Bacon Island are deeper than those in Webb Tract. The groundwater levels are largely affected by the irrigation and drainage system within the islands. Static groundwater levels were not recorded due to the immediate backfill of the borings with soil cuttings. Accordingly, the static water levels are expected to be shallower than those measured at the time of drilling.

5.4.4 Estimated Available Borrow Volumes

The potential borrow areas on Webb Tract and Bacon Island were delineated based on maintaining a distance of at least 1,500 feet between the borrow areas and the crests of the existing island levees and encompassing areas that have no more than 15 feet to the top of potential sandy borrow materials. The borrow area delineations are shown on Figures 4 and 5 for Webb Tract and Bacon Island, respectively. These figures also show the depths to the top of sandy borrow materials adjacent to the borings and CPTs.

Table 5.3 summarizes the acreage of the potential borrow areas, estimated volume to remove peat and other unacceptable overburden soils, estimated borrow material volumes available within 15 feet of the ground surface, and ratios of overburden volume to borrow volume.

Table 5.3: Summary of Available Borrow Volume Estimates

Estimated Area/Volume	Webb Tract	Bacon Island
Delineated Area (acres)	2330	2620
Volume of Overburden Excavation (CY)	36.9 million	49.6 million
Volume of Potential Borrow Materials within 15 feet of the Ground Surface (CY)	19.5 million	13.8 million
Ratio of Overburden Volume to Borrow Volume	1.9:1	3.6:1

It is anticipated that the sandy borrow materials would be mined by excavators, mostly below groundwater level, and stockpiled to drain, since groundwater may be as shallow as 2 feet or 3 feet below the ground surface. Moisture conditioning of the soils may require disking and aerating. After the soils are moisture conditioned for compaction, they would be hauled to the embankment locations along the perimeters of the islands.

Details on the borrow material investigations are given in the URS Borrow Area Geotechnical Report, Draft Report June 2003.

5.5 Integrated Facilities Engineering Design and Analyses

5.5.1 Components of the Integrated Facility

The integrated facilities are consolidated control structures that will be used to control the diversion and release of water onto and off of the reservoir islands. There are a total of four integrated facilities, two on Webb Tract and two on Bacon Island (Figures 2.1 and 2.2). The key features of each integrated facility are:

- fish screen is isolated from the other controls with a transition pool,
- storage diversions and releases can occur when the river and reservoir are at different levels, allowing for year-round operations,
- diversions and releases are optimized with gravity flow and pumping combinations
- required flow under gravity is possible with small head differences, and
- low midbay level and pumping units allow for complete drainage of reservoir when necessary

The main components of the integrated facilities are shown in Figure 5.3 and are also described as follows.

Fish Screen Facility: The fish screen facility is located at the entrance to the integrated facility and is oriented adjacent and parallel to the river channel. The objective of the fish screen facility is to pass the design diversion rate over a range of water levels in both the river channel and the reservoir while protecting juvenile fish from entrainment, impingement and migration delay.

Transition Pool: The transition pool is located immediately downstream of the fish screen facility. The purpose of the transition pool is to separate the fish screen from the other operational controls, create a smooth transition of flow from the very wide section of the fish screen facility to the narrow section at Gate #1, and act as a settling basin to prevent excess suspended silt from entering the reservoir.

Gate Structures: Each integrated facility consists of three gate structures. Each gate structure operates strictly by gravity flow and serves a unique purpose in the integrated facility operations. Gate #1 is used strictly during diversion operations to regulate flows into the midbay. Gate #2 is used to regulate the flow of water from the midbay to the reservoir during diversion operations. Gate #2 can also be used to regulate the flow of water out of the reservoir and into the midbay during release operations. Gate #3 is used strictly during release operations to regulate flows from the midbay into the bypass channel.

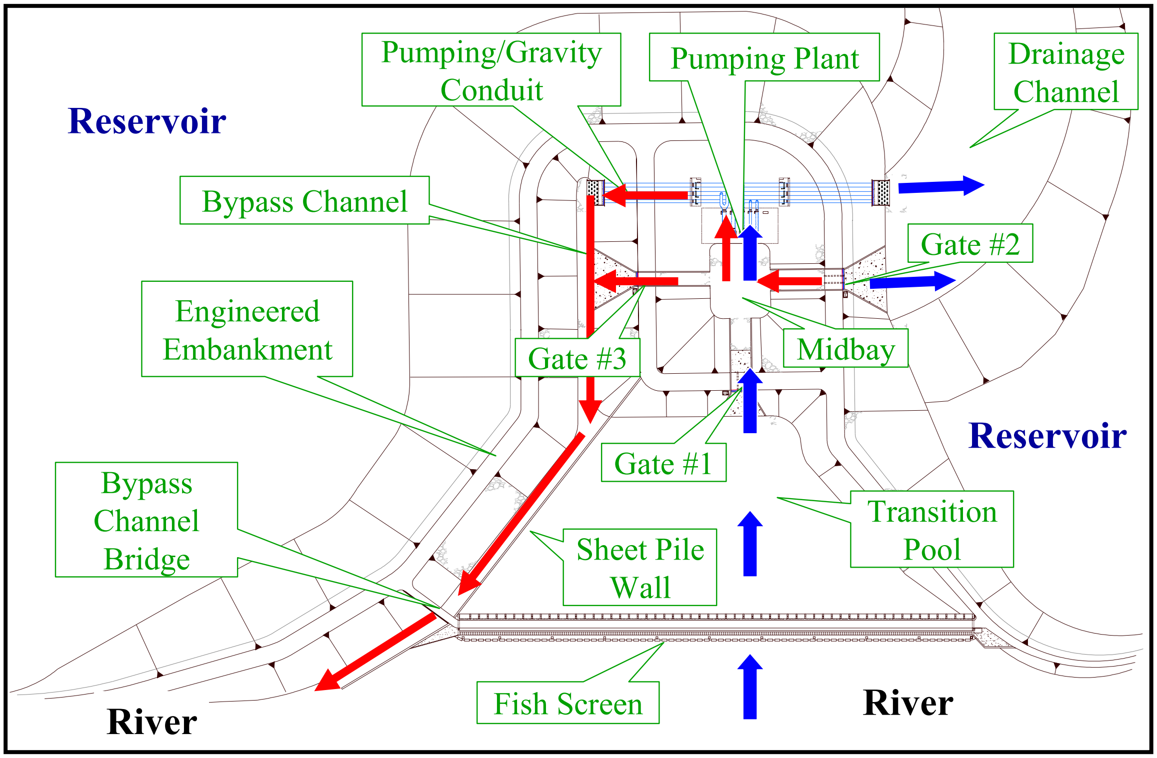
Midbay: The midbay is located at the center of the integrated facility gate structures and pumping plant. The midbay serves as a flow regulation pool during diversion and release operations. It also serves as a forebay for the pumping plant when it is operating.

Pumping Plant and Conduit: The pumping plant is located adjacent to the midbay on the side opposite to Gate #1 and the conduit pipes stretch from the reservoir side of the integrated facility to the bypass channel. The pumping plant serves two main purposes: (1) to supplement diversion and release gravity flows when sufficient head is not available at the gate structures to meet the desired flow rates by gravity and (2) to meet the desired flow rate when the net head is zero or negative at the gate structures. The pumping plant consists of five pumping units, three pumps with a capacity of 400 cubic feet per second (cfs) each and two pumps with a capacity of 150 cfs each, totaling a maximum pumping capacity of 1,500 cfs. The pumped flows will be routed through the conduit pipes, which are used to discharge water into the reservoir and bypass channel during diversion and release pumping operations, respectively. The conduit pipes can also be used for gravity flow releases to supplement the gravity flow releases through Gate #3.

Bypass Channel: The bypass channel is used to convey reservoir releases into the river. Reservoir releases enter the bypass channel at its upstream end through the conduit pipes and/or through Gate #3. The bypass channel is isolated from the fish screen facility and transition pool by a structural sheet pile wall. A vehicle access bridge spans the bypass channel and is connected on one end to the integrated facility embankment and on the other end to the fish screen structure.

Embankments: Engineered embankments will surround the integrated facility on the reservoir side and will surround the midbay on all sides. All embankments will have 3H:1V side slopes on both the interior and exterior slopes. Riprap slope protection will be placed on all embankments along the entire slope.

Figure 5.3: Typical Integrated Facility Layout



5.5.2 Integrated Facilities Design

A number of hydraulic analyses were conducted to determine the overall layout of the integrated facilities. The objectives of the hydraulic analyses were to determine the size and optimize the configuration of the integrated facility components, and to develop flow rating curves for each integrated facility showing the percentage of time the design flow can be met by gravity flow only, pumped flow only, or a combination of gravity and pumped flow.

Mechanical designs were prepared for the pumping plants, conduits and gate structures and an electrical analysis was performed to size the transformers required to supply power to each integrated facility. Structural analysis and design was prepared in sufficient detail to allow a feasibility-level cost estimate of the four proposed integrated facilities to be completed. In particular, structural analysis and design was completed for the structural components of the fish screen structure, the three gate structures, structures associated with the pumping stations and conduits, and for the sheet pile walls. Details on the integrated facilities design are given in the DWR Integrated Facilities Engineering Design and Analyses, Draft Report June 2003.

5.6 Construction Methods and Cost Estimation

The third phase of work was to analyze suitable construction methods, perform construction scheduling and estimate total project construction costs related to construction of both the "rock berm" and "bench" embankment options and construction of the four integrated facilities. Information developed under the construction methods and cost estimation work was used in the risk analysis.

Under the embankment construction methods and cost estimate investigation, two methods of extracting sandy materials (from underneath the peat soils) suitable for embankment construction were considered, depending on whether or not dewatering is required. With the availability of efficient dragline operations it was decided that dewatering of borrow areas is not needed to excavate borrow materials. A two stage construction method was developed that included stockpiling excavated borrow materials, drying and then transporting it to the embankments for desired compaction. Loss of materials was included in the embankment fill quantity estimates. Quantity estimates for slope protection, piping protection and seepage control (pumping wells) were also developed. As recommended by the DWR Independent Board of Consultants, filter fabric lining was provided on the interface between existing levees and the new embankments and also on the reservoir side of the new embankment as shown in Figure 5.2. Slopes steeper than 10:1 were protected with rip rap protection on all sides of the reservoirs. For 10:1 north and west facing slopes soil cement with bentonite mix, similar to the recently (2002) completed work on Clifton Court Forebay, was selected after a comparison of construction costs with rip rap protection.

Under the integrated facilities construction methods and cost estimate investigation, quantity estimates were developed for all integrated facility components, which include the fish screen facilities, gate structures, pumping stations, conduit pipes and associated outlet structures, bypass channel bridge structures, and sheet pile walls. Applicable methods for constructing the various embankment, earthwork, and integrated facility components were reviewed and the most feasible methods were evaluated. Details on task sequencing and overall construction scheduling were also developed. The original design of the foundations for integrated facility included pile foundations for structures and embankments surrounding the facilities were to be constructed over the existing soft soils. However, the DWR Independent Board of Consultants recommended that the soft soils be removed and replaced by mineral soils, eliminating the potential for the embankments to settle near the structures. This change resulted in an increase in cost of construction not realized during the 2001 Joint USBR/DWR Planning Study. This kind of increase is expected from the planning design stage to the feasibility level. Additional costs are related to excavation of soft materials, sheet piling around foundation areas, dewatering foundations, sheet piling in the existing levee next to the fish screen structure for stability and back filling embankments and structural foundations with mineral soils.

An overall project construction schedule was developed for embankment and integrated facilities construction. The schedule reflects total construction duration of 6 years, working about 8 months per year (between April and November). The contractor would need to keep a work force on site to monitor, maintain and repair the earthworks during the winter months. The schedule shows the basic sequence of construction activities and that work on both islands would proceed concurrently.

The project cost estimates are affected by factors such as unit pricing, construction methods to be used and construction duration. Market research was performed, including quotations from contractors and suppliers, to obtain relevant unit costs for acquiring different construction materials and transporting them to the project site. The cost of labor and equipment required for placement of these materials was also obtained. Feasibility-level cost estimates were then prepared for constructing the earthwork components for the two embankment options and for constructing the four integrated facilities.

To include the impact of global warming and climate change, resulting sea level rise was considered for engineering costs estimates. Based on climate impact studies conducted by various agencies, climate change may cause a slow rise of 0.5 feet in the Delta water levels over the 50-year life of the project. This rise can be easily handled by normal annual embankment maintenance operations over the next 50 years and additional costs were included in the annual operation and maintenance cost estimates.

A summary of the In-Delta Storage Project costs is given in Table 5.4. Details on the construction methods and cost estimates for embankments are given in the URS Earthwork Construction Cost Estimate, Draft Report June 2003. Details on the integrated facility construction methods and cost estimates are given in the Integrated Facility Structures Cost Estimate, Draft Report June 2003.

5.6.1 Miscellaneous Costs

In addition to the embankment and integrated facilities construction costs, miscellaneous costs were considered in the cost estimates to determine the total cost of the project. These costs included: land acquisition, environmental mitigation, demolition and hazardous materials clean up, electrical relocations including new power lines and PG&E pipeline replacement on Bacon Island.

The cost of land acquisition represents the property value based on its current use. An appraisal study is in progress; however, results of the appraisal study will be confidential and land acquisition costs will be negotiated during future phases of the work. Information on mitigation costs is given in Chapter 6 of this report. Costs for demolition and hazardous materials clean up were provided by the DWR Environmental Services Division. PG&E pipeline and power line relocation costs were estimated by DWR.

5.6.2 Cost Contingencies

Project contingency costs were assumed to vary for embankment earthwork and integrated facilities construction. Generally, contingencies are equal to 20 percent of the base construction estimates. Due to uncertainties of material estimates, a value of 25 percent was used for embankments earthwork and integrated facilities earthwork. A 20 percent contingency cost was included for integrated facility structures and mechanical and electrical components.
The percentages used for engineering design, construction administration and legal costs vary depending upon the study level.

	Range	Average
Engineering Design	6-10%	8%
Construction Administration	6-10%	8%
Legal	2-5%	3%
Total	10-25%	19%

Detailed cost estimates presented in the engineering cost reports include a value of 5 percent for contractors engineering, construction and administrative management. For the final adjustment to engineering, construction management and legal costs, an additional 20 percent of the subtotal of the base construction estimates plus contingencies was added. This cost component would account for project planning as well as engineering design (final design) and construction management. Lastly, legal and administrative costs associated with land acquisition, construction contracts and infrastructure relocation are also considered in this component. Both of these assumptions are typical for projects of this magnitude.

5.6.3 Annual Operation and Maintenance Costs

Annual operation and maintenance costs for the project are given in Table 5.4. These costs include costs for embankment maintenance, pumps, conduits and fish screens maintenance, seepage system operation and monitoring, habitat islands operations, fisheries monitoring, weed control, cultural resources mitigation and in-lieu payments for property taxes. Further details are presented in the DWR Draft Engineering Investigations Summary, July 2003 and the DWR Draft Report on Environmental Evaluations, July 2003. Over the 50-year economic life of the project, embankments will need to be raised approximately six inches to accommodate the rise in sea level due to climate change. These additional costs are included in the annual operation and maintenance cost.

5.7 Risk Analysis

The fourth and final phase of work was to complete an overall risk analysis. The purpose of the risk analysis was to evaluate the risk and consequences of failure of the existing levees and In-Delta Storage re-engineered project embankments and integrated facilities under all loading events (operational, seismic, and flooding) and estimate the loss-of-life risk and economic losses through uncontrolled releases. The risk analysis was conducted in accordance with the general USBR risk analysis guidelines. The results of the analysis were used to evaluate the expected project performance relative to the “no action” alternative (i.e., existing levees).

Information regarding historical losses in past levee failures was reviewed and compiled. Then the zone of impact under each risk scenario was assessed and the environment and resources that would be impacted were identified. Finally, the economic losses associated with the consequences of an inward breach, an outward breach, and flooding a neighboring island were evaluated and the dollar values associated with these economic losses were estimated.

As per engineering review by the DWR Independent Board of Consultants, the project could be implemented at an acceptable level of risk with a cost estimate that should not vary between the 20 to 30 percent contingency range allowed in standard cost estimation for projects of this type. The seismic risk of implementation cannot be avoided and is similar or better than all other projects already constructed in the Delta. To reduce this risk, it is recommended that the existing levees be upgraded to an acceptable level of seismic risk. Details on the risk analysis are given in the URS Risk Analysis, Draft Report June 2003.

Table 5.4: Summary of In-Delta Storage Project Costs

Item	Amount	
1. Island Embankments [1]		
Webb Tract	$ 87,428,000	
Bacon Island	$ 90,067,000	
2. Seepage Control System	$ 12,200,040	
3. Instrumentation	$ 3,000,000	
4. Mobilization for Embankment Construction [2]	$ 14,986,000	**$ 207,682,000**
5. Integrated Facility Embankments [3]		
Webb Tract @ San Joaquin River	$ 19,585,500	
Webb Tract @ False River	$ 17,357,300	
Bacon Island @ Middle River	$ 18,974,950	
Bacon Island @ Santa Fe Cut	$ 15,250,150	**$ 71,168,000**
6. Integrated Facility Structures [3]		
Webb Tract @ San Joaquin River	$ 36,830,697	
Webb Tract @ False River	$ 35,002,266	
Bacon Island @ Middle River	$ 36,694,504	
Bacon Island @ Santa Fe Cut	$ 38,415,855	**$ 146,944,000**
7. Miscellaneous		
Land Acquisition (may vary, subject to negotiations)	$ 60,000,000	
Mitigation	$ 34,450,000	
Demolition & Hazardous Materials Clean Up	$ 8,000,000	
PG&E Pipeline & Electrical Relocation	$ 15,000,000	
Permits	$ 300,000	**$ 117,750,000**
SUBTOTAL		**$ 543,544,000**
Contingency for Island Embankment Earthwork (25%)		**$ 44,374,000**
Contingency for Facilities Earthwork (25%)		**$ 17,792,000**
Contingency for Facility Structures and Others (20%) [4]		**$ 31,014,000**
Contingency for Miscellaneous (15%) [5]		**$ 8,618,000**
Subtotal with Contingencies		**$ 645,342,000**
Costs for Eng Design, Const Mgmt, Admin & Legal [6]		**$ 129,069,000**
TOTAL COST		**$ 774,411,000**
Annual Operation & Maintenance Costs [7]		$ 5,873,000

1 Costs are based on using 12-inches of Soil Cement for 10:1 reservoir side slope protection

2 Includes mobilization for island embankments, seepage control and instrumentation

3 Costs include mobilization at each facility

4 "Others" include Seepage Control System and Instrumentation and does not include mobilization costs

5 Excludes Land Acquisition and Permits Costs

6 This cost is 20% of Subtotal with Contingencies

7 A description and breakdown of the Annual O&M Costs are provided in the Engineering Summary Report

Chapter 6: ENVIRONMENTAL EVALUATIONS

6.1 General

DWR conducted additional environmental evaluations of the In-Delta Storage Project. The environmental evaluations were based on the recommendations made in the DWR/CALFED joint planning study In-Delta Storage Program Report on Environmental Evaluations, May 2002. The evaluations are based on new surveys, studies, and existing information available at the time of the State Feasibility Study. The areas covered in the study included: land use, botanical resources, wildlife resources, cultural resources, aquatic, hazardous materials, and recreation. A brief explanation of mitigation measures is also included for mitigation of project impacts.

Detailed information on the environmental evaluations is available in *In-Delta Storage Program Draft State Feasibility Study Report on Environmental Evaluations* dated June 2003.

6.2 Land Use

During the 2002 public review and CALFED Science review periods, DWR staff received conflicting comments on the impacts of the In-Delta Storage Project on agricultural land and the need for mitigation. Results from the Land Evaluation and Site Assessment (LESA) indicated that conversion of Webb Tract and Bacon Island from agricultural uses to reservoir storage will result in a significant impact to agricultural land. A LESA evaluation was not completed for Holland Tract and Bouldin Island since the detailed use of the islands under the revised Habitat Management Plan was unclear at the time of the evaluation. The purchase of agricultural easements to mitigate the impacts of converting Webb Tract and Bacon Island to nonagricultural uses could cost up to $12 Million. Additional work should be done to determine the implications of acquiring 10,003 acres of agricultural easements on the financial feasibility of the In-Delta Storage Project and the implementation of ERP actions in the Delta.

Webb Tract contains a 139-acre parcel that is under Williamson Act contract which prohibits conversion of agricultural land to other uses. Approximately 4,662 acres of Bacon Island are currently under Williamson Act contracts. Public agencies, such as DWR or Reclamation, may acquire land that is under Williamson Act contract when the agency needs to locate a public improvement on the land.

6.3 Botanical Resources

DWR botanists conducted special status plant surveys in spring through fall 2002. The 2002 surveys located 111 occurrences of special status plant taxa on the exterior levees of the project islands, 34 more than were found in the 1988 surveys. No occurrences were found in the interior of any island in 2002. The populations of three special status plant species on the levees increased and one decreased from levels seen in 1988. Botanists also identified a new species not previously found in the Delta. Impacts from levee modifications or placement of additional riprap will occur to

5 special status species. Mitigation for levee modifications/riprap can be incorporated into the Habitat Management Plan.

6.4 Wildlife Resources

DWR biologist conducted wildlife surveys and habitat assessments for listed and special-status species to determine the potential impacts and mitigation required under federal and State environmental laws. DWR updated species and habitat information during 2002 and 2003 for the giant garter snake, western pond turtle, greater sandhill crane, Swainson's hawk, California black rail, western burrowing owl, tricolored blackbird, loggerhead shrike and bats.

DWR determined that additional suitable habitat for the giant garter snake was present on Webb Tract, Bacon Island, Bouldin Island, and Holland Tract. Western pond turtles were found on and near all the project islands. The number of nesting Swainson's hawks on or near Webb Tract and Bacon Island increased. Also, greater sandhill cranes were located on all project islands. Crane foraging habitat has increased by 38 percent from 1988. DWR biologist did not locate any California black rails on the adjacent in-channel islands. Loggerhead shrikes were located on all project islands, but were more abundant on Holland Tract and Bacon Island. Nesting tricolored blackbirds were not located on the project islands. Wintering tricolored blackbirds were identified on Bacon Island and Webb Tract foraging. Burrowing owls were not found on any of the project islands. Suitable bat foraging and roosting habitat was identified on all project islands, however, active bat roosts were not detected.

DWR developed a revised Habitat Management Plan that includes specific habitat types and amounts to mitigate for the potential impacts to giant garter snake, Swainson's hawks, greater sandhill cranes and the other special-status species. The habitat types include: emergent marsh, permanent pond, canal, cottonwood-willow woodland, great valley willow scrub, herbaceous upland, corn, wheat, alfalfa and other harvested crops. Additionally, a total of 3,900 acres of conservation easement would be required to fully mitigate for impacts to Swainson's hawk foraging habitat. The original DW HMP was revised by DWR and includes mitigation for wetlands and open water impacts.

6.5 Aquatic Resources

6.5.1 General

Nine listed or sensitive fish species occur in the In-Delta Storage Project area that could be affected by the project. The species include chinook salmon, delta smelt, splittail and Central Valley steelhead. A California Endangered Species Act Incidental Take Permit issued by the Department of Fish and Game, the U.S. Fish and Wildlife Service and National Marine Fisheries Service (NOAA Fisheries) biological opinions, and the State Water Resources Control Board Decision 1643 included provisions in the Delta Wetlands Project (DW) permit to protect them. In general, impacts could be adverse or beneficial. These are related to: changes in channel water temperature, dissolved oxygen concentrations, outflow and flow patterns, salinity and organic carbon, transport flows, increased entrainment of eggs and larvae, and changes in mercury concentrations in water and biota due to reservoir and habitat island operations.

DW Permit Final Operations Criteria (FOC) for fisheries developed under the biological opinions were included in reservoir operations stated in Chapter 3 to ensure that project operations do not jeopardize the continued existence of delta smelt, splittail, chinook salmon or Central Valley steelhead. Other species are also expected to benefit from the FOC. As long as the FOC are met, adverse impacts to listed fish species are considered less than significant. The 1997 DW Project fish screen design did not meet DFG 2000 Fish Screening Criteria. Therefore, the proposed DW design required modification to meet current criteria. The fish screens were redesigned to bring the screens into compliance with current standards that meet the restrictions in the FOC, biological opinions, and incidental take permit.

The delta smelt diversion criteria in D 1643 results in reduction of project yield. Details of operational runs for fisheries operations are given in Chapter 3 on Operations. Recently, the California Farm Bureau Federation reached a settlement agreement in their lawsuit against the U.S. Fish and Wildlife Service when the Service agreed to complete a five year status review. The California Farm Bureau Federation claims that current delta smelt recovery criteria are based on unjustified abundance and distribution assumptions. Developing current size and distribution estimates for delta smelt abundance is difficult. Predicting the size and distribution of delta smelt abundance well into the future is an area of even more uncertainty. Any future negotiated changes in the criteria will be incorporated in the reservoir operations.

Additionally, further analysis is required to narrow down the uncertainty due to changes in the Dissolved Oxygen (DO) levels as a result of the project operations. Predicting DO levels for specific areas would require estimations of highly variable and complex biological dynamics.

6.5.2 Species in the Project Area

The In-Delta Storage project could have positive and negative effects on protected fish species in the Bay-Delta. According to the California Natural Diversity Database records, and species lists provided by USFWS and DFG, there are seven threatened or endangered fish species, two candidates for listing, and five species of special concern that could be in the project area. A list of these special status fish species is provided in Table 6.1. A brief description of the life histories of these species and specific discussion on how the project could affect these species was provided in the In-Delta Storage Program Planning Study Report on Environmental Evaluations, May 2002. Additional fisheries impact analyses will be needed as changes in reservoir operations are proposed in project development. For example, a flow-through, circulation operation proposed for the reservoirs might change how the project could affect fish species in the channels surrounding reservoir islands. Increases in certain types of organic carbon in the surrounding channels could also prove beneficial to the species.

Table 6.1: Special Status Species for the In-Delta Storage Project

Common Name	Scientific Name	Federal Status	State Status
Winter-Run Chinook Salmon	*O. tshawytscha*	Endangered	Endangered
Spring-Run Chinook Salmon	*O. tshawytscha*	Threatened	Threatened
Late Fall-Run Chinook Salmon	*O. tshawytscha*	Candidate	Special Concern
Fall-Run Chinook Salmon	*O. tshawytscha*	Candidate	Special Concern
Central CA Coastal Coho Salmon	*O. kisutch*	Threatened	Endangered[a]
Central CA Coastal Steelhead	*O. mykiss*	Threatened	None
Central Valley Steelhead	*O. mykiss*	Threatened	None
Delta Smelt	*H. transpacificus*	Threatened	Threatened
Splittail	*P. macrolepidotus*	Threatened	Special Concern
Longfin Smelt	S. thaleichthys	Special Concern	None
Green Sturgeon	*A. medirostris*	Candidate	None
River Lamprey	*L. ayresi*	Special Concern	None
Kern Brook Lamprey	*L. hubbsi*	Special Concern	None
Pacific Lamprey	*L. tridentata*	Special Concern	None

[a]Not included in the DFG Species List for In-Delta Storage

6.5.3 Fish Screens Design Coordination

DWR met with the Central Valley Fish Facilities Review Team (CVFFRT) on January 17, 2003 and on February 13, 2003 to solicit technical comments and suggestions on the proposed design and layout of In-Delta Storage Project fish screening facilities. Technical experts from various resource agencies provided suggestions to improve the fish screen design and layout, which were incorporated into the plans. The CVFFRT recommended that a technical review committee on the In-Delta Storage Project fish screens be set up in later stages of the project. For specific information on the fish screens design refer to the In-Delta Storage Program Draft Engineering Investigations Summary, June 2003.

6.5.4 Shallow Water Habitat Impacts and Mitigation

The In-Delta Storage Project includes strengthening levees by placing rock on the riverside of the reservoir islands to assure levee stability. Preliminary estimates are that levee protection measures could eliminate 80 acres of shallow water habitat from the perimeters of Bacon Island and Webb Tract. Mitigation cost estimates for the loss of shallow water habitat are around 2 million dollars. Additional analysis will be conducted to determine the specific impacts to shallow water habitat once the levee protection measures and recreation development plans are refined. Also, DWR will consult and coordinate with resource agencies to develop shallow water habitat mitigation strategy.

6.6 Cultural Resources

A substantial amount of previous cultural resource compliance work has been conducted for the Delta Wetlands Project. The previous cultural resource studies were conducted from 1988 -1993 and were conducted in accordance with the requirements of Section 106 of the National Historic Preservation Act. Delta Wetlands Properties identified sensitive cultural resources on all the project islands. Significant archaeological sites exist within project lands on Bouldin Island, Bacon Island, and Holland Tract. Areas of sensitive soils potentially containing prehistoric human remains exist on Webb Tract and Holland Tract.

The identification of significant cultural resources and areas sensitive for prehistoric archaeological remains led to the 1998 *Programmatic Agreement Among the U.S. Army Corps of Engineers, California State water Resources Control Board, California State Historic Preservation Officer, Advisory Council on Historic Preservation, and Delta Wetlands Properties Regarding the Implementation of the Delta Wetlands Project* to ensure adequate treatment of historic properties. The 2002 In-Delta Storage Project Study Report on Environmental Evaluations built upon the programmatic agreement and recommended that DWR re-initiate Section 106 consultations, update the Programmatic Agreement (PA), re-survey Piper Sands and conduct data recovery excavations. The 2002 Report also acknowledged the need to develop a Historic Properties Management Plan (HPMP), as outlined in the PA, to mitigate the adverse effects of the project on historic properties and to address the management of cultural resources once the proposed project has been implemented. DWR and Reclamation agreed to have DW consultants prepare a HPMP that would serve the In-Delta Storage Project or the DW project, whichever proposal successfully went forward. DWR and Reclamation met with the DW consultants in the fall of 2002 to discuss the content of the HPMP; the draft HPMP (Wee et al. 2003) was completed in January 2003.

6.6.1 Historic Properties Management Plan (HPMP)

The HPMP closely matches the May 2002 In-Delta Storage Program Environmental Evaluations Report recommendations with few variations. A comparison of the salient points is presented below.

Webb Tract

The 2002 report recommended that the Piper Sands on Webb Tract be re-surveyed for archaeological resources prior to implementation of the Delta Wetlands Project. Should archaeological sites be identified, they would require evaluation for significance.

The HPMP also recommends that a reassessment of these soils but, in addition to survey/surface examination, it calls for trenching of the Piper Sands to identify the presence of buried deposits and, more specifically, human interments. Trenching would focus on Piper Sands above sea level and it is proposed that 15 to 20 trenches, measuring between 3 and 10 feet long, be excavated to a depth of 10 to 15 feet below the surface. The HPMP further recommends that the Piper Sands be monitored for the possible exposure of human remains from erosion after the project has been implemented. Thus the HPMP proposes additional, but appropriate, assessment and monitoring measures in comparison to the 2002 report.

Holland Tract

As at Webb Tract, the 2002 report recommended that the Piper Sands on Holland Tract be resurveyed for archaeological remains and, should any sites be identified, that they be evaluated for significance. The Study Report also recommended that all previously-identified sites be revisited and that records for each site be updated. Even though two previously-recorded sites on Holland

Tract have been determined ineligible for the National Register, due to the known presence of human remains at the sites, it was proposed that some form of mitigation be carried out at those sites prior to implementation of the Delta Wetlands Project, if the sites could not be avoided. DWR continues to recommend this level of documentation.

The HPMP proposes somewhat less work for Holland Tract. The HPMP recommends that one site, CA-CCO-593, be monitored for the possible exposure of human remains after the Delta Wetlands Project has been implemented.

Bacon Island

Given the presence of a Rural Historic District on Bacon Island, the 1998 PA and the 2002 report recommended a number of measures to mitigate the effects of the Delta Wetlands Project on the historic cultural resources. The only significant difference between the 2002 report and the HPMP pertains to the level of data recovery at the historic-era archaeological sites contained within the Historic District. The 2002 study proposed that data recovery activities be conducted at each of the ten archaeological sites located there. The HPMP, on the other hand, proposes data recovery efforts at only six of the sites. This recommendation comes as the result of conducting minor shovel probes at the sites to determine the presence of a subsurface deposit, whereby a sufficient deposit was identified at six of the ten sites. Additional mitigation activities, such as recording the architectural features of the Historic District according to the Secretary of the Interior's Standards and Guidelines for Architectural and Engineering Documentation: HABS/HAER Standards, the production of an educational documentary and a public education publication are consistent with the requirements of the PA and the recommendations of the 2002 report.

Bouldin Island

One historic-era archaeological site on Bouldin Island has been determined eligible for the National Register of Historic Places. The 2002 report and the HPMP recommend data recovery for this site.

The HPMP provides greater detail than the 2002 report for conducting some required tasks (e.g., Native American consultation, activities related to unexpected archaeological finds, etc.), all of which is consistent with the requirements of the PA.

6.7 Hazardous Materials

DWRs' Site Assessment Section conducted a Phase II Environmental Site Assessment (ESA) for the In-Delta Storage Program. The purpose of this Phase II ESA was to evaluate the nature and extent of suspected hazardous substance contamination as identified in the modified Phase I ESA for the Site dated December 2001. In September 2002, DWR staff collected a total of 77 soil samples at the Site. High levels of petroleum hydrocarbons, such as oil and grease, were detected at the vehicle and farm equipment maintenance facilities, especially in areas around or near fuel and lubricating oil tanks. Low concentrations of other potential contaminants, such as heavy metals, chlorinated pesticides, and organic solvents were also detected on each property. However, in each instance, their levels never exceeded the Total Threshold Limit Concentrations as established in California regulations.

Based on the results of the Phase II ESA sampling, DWR staff recommends further investigation of the identified “hot spot” areas to better delineate the extent of contamination. Further investigation may include more invasive subsurface soil sampling, surface water and groundwater sampling, and environmental fate studies for each of the contaminants of concern. DWR staff also recommends that any contaminated soil at or near water supply well sites be removed and properly disposed of, or remediated, depending on the extent of contamination.

Lastly, DWR staff recommends that all measures be taken to indemnify the State/federal government from any liability associated with future hazardous substance contamination or remedial actions associated with the natural gas wells that are present throughout the Site. At this time, these gas wells and the parcels on which they are situated may not be part of the land acquisition for the project. Such measures may include establishing baseline soil and groundwater sampling data for the properties surrounding the gas wells or inserting indemnification clauses in each of the proposed purchase agreements.

6.8 Recreation

The Davis-Dolwig Act (Act) declares that recreation and the enhancement of fish and wildlife resources are among the purposes of State water projects and acquisition of real property for such purposes be planned concurrently with the project. The Act applies to water storage projects constructed by the State or by the State in cooperation with the Federal government. DWR’s responsibilities under the Act include planning for recreation and for fish and wildlife preservation (mitigation) and enhancement, and acquiring land for such uses. The recreational features mentioned in the Act include campgrounds, picnic areas, water and sanitary facilities, parking areas, viewpoints, boat launching ramps, and any others necessary to make project land and water areas available for use by the public. DWR planning for public recreation use and fish and wildlife preservation and enhancement is to be part of the general project formulation activities and done in close coordination, consultation, and cooperation with Parks, DFG, Department of Boating and Waterways, and all appropriate federal and local agencies. DWR is to give full consideration to the recommendations provided by such other departments and agencies, and local recreation groups.

Changes to the recreation plan may be made during the Subsequent EIR/EIS and ESA/CESA consultation process and during discussions with State Parks, Boating and Waterways, Delta agencies and local recreation groups. Potential conflicts may exist between the proposed hunting and sandhill crane use on the habitat islands. Boat dock placement should consider the existing special status plant populations on all levees. It should be possible to modify the recreation plan to accommodate both recreation and threatened and endangered species needs

6.9 Mitigation Measures

A summary of the mitigation measures and costs estimates is given in Tables 6.2 and 6.3.

Table 6.2: Estimated Initial Environmental Mitigation and monitoring costs

Mitigation and Monitoring	Initial Cost
Purchase conservation easements (3,900 acres)	$ 4,680,000
Cultural resources mitigation	$ 945,000
Recreation	$ 3,200,000
Environmental Site Assessment	$ 135,000
Slough side mitigation	$ 2,000,000
Habitat Islands development and construction	$ 23,490,000
Total Cost	**$ 34,450,000**

Table 6.3: Estimated Annual On-Going Costs for Environmental Mitigation, Monitoring and Weed Control

Mitigation and Monitoring	Annual Costs
Habitat island, fisheries monitoring and operations and maintenance	$1,700,000
Cultural resources mitigation	$10,000
Invasive weed control on reservoir islands	$722,000
Recreation facilities operation and maintenance	$265,000
Total annual costs	**$2,697,000**

6.10 Findings and Recommendations

- Because the proposed changes in the project diversions and operations are different than those stated in the SWRCB Decision 1643, subsequent CEQA/NEPA documents would be required for any changes in environmental impact evaluations.
- Due to their strategic location, the operation of the island reservoirs may contribute to an incremental improvement in habitat quality and availability for fish and other aquatic organisms inhabiting the Bay-Delta system. On the other hand there may be adverse impacts in some areas. Fisheries impact analyses should be conducted for future changes in reservoir operations.
- Organize a technical review committee for In-Delta Storage Project fish screens review during the preliminary and final design phases.
- Coordinate with fishery agencies to determine the appropriate means of achieving endangered species acts compliance.

Chapter 7: ECONOMIC ANALYSIS

7.1 General

An assessment of potential costs and benefits is an important part of the feasibility study process. Typically, project decision-makers compare estimates of benefits and costs to determine if a proposed project warrants further consideration and possible implementation. If estimated benefits compare favorably with estimated costs, then environmental documents and necessary permits are finalized, and financial feasibility is assessed. An economic analysis of the In-Delta Storage project is particularly challenging due to the wide variety of ways the project could be operated and the resulting end places and use of water supplies produced by the project. Moreover, estimating the future value of water supplies to any given region is a difficult prospect because of the many factors which could affect that value, such as the magnitude of future demand for additional water and the cost and availability of other options for meeting those demands.

This chapter presents information on 1) the conversion of project construction and operation costs into annual equivalent cost; 2) a preliminary assessment of potential project benefits, including the use of urban and agricultural economic models to estimate the value of project water supply improvements; 3) the project impacts on the Delta regional economy; and 4) recreational benefits. While a preliminary assessment of the monetary value of potential project benefits is included in this draft report, DWR acknowledges that additional input from economic experts and potential project participants is needed to refine this assessment. To demonstrate the need for this refinement, this chapter includes a sensitivity analysis of the estimate of the monetary value of urban water supply benefits the In-Delta Storage project might provide. As described below, this analysis shows that these benefits estimates are very sensitive to assumptions about the cost and availability of regional water use efficiency options (e.g., conservation, wastewater recycling, groundwater reclamation etc.) and how much value water users place on water system reliability. A final assessment of project benefits will require refinement of these assumptions and further work to determine the value of other benefits described in the draft report that have not yet been quantified.

7.2 Methodology

For the purpose of economic assessment of the In-Delta Storage Program, DWR established a methodology using available economic models to quantify potential benefits. Project deliveries input to the economic models was created by the CALSIM model which simulates project operations using a 73-year historic hydrology as described in Chapter 3, Operation Studies.

This initial simulation provides an estimate of direct increased water deliveries to urban and agricultural water users, as well as an assessment of additional water supply benefits that might be allocated to increase stream flows for the benefit of fisheries and water quality, provide supplies to the Environmental Water Account, provide additional supplies for direct delivery or transfer to agricultural or urban water users. The tables in the following sections show estimated benefits for the Sample Scenarios. Other variations in project operations are possible and may be identified in subsequent analysis or negotiations. The estimated benefits of the project will be re-assessed when alternative operations are identified. A sensitivity analysis for the example Sample Scenario 2 was done to determine the variations in potential benefits as a result of changes in assumptions for the urban economic models.

Economic analysis information presented in this chapter is based on evaluation of equivalent annual cost of project implementation including costs of project development, construction, mitigation and operation and maintenance, and benefits of the project. The engineering and environmental studies evaluated the capital cost of building the project and mitigation required for project impacts. The operation and water quality studies provided information on potential benefits of the In-Delta Storage Project. Two types of economic analyses were done for this study. First, benefit and cost information from operations, water quality, engineering and environmental evaluations became input for the economic justification for the proposed project. Second, a project area economic impact analysis was done to disclose the potential for both positive and negative impacts to the economy of the local area.

7.3 Project Capital Cost

Project Capital Cost includes the following.

- Total Construction Cost including engineering design, construction management and legal administration as given in Table 5.4 in Chapter 5.
- Regulatory costs
- Forgone Investment Value

Capital project cost including the construction cost, regulatory cost and foregone investment Value are given in Table 7.2. The procedure used in estimation of regulatory cost and foregone investment value is discussed in Sections 7.3.1 and 7.3.2.

7.3.1 Regulatory Costs

Regulatory costs reflect documentation, permitting and initial monitoring and mitigation expenses. Estimated initial environmental mitigation and monitoring costs are given in Table 6.3 in Chapter 6.

7.3.2 Forgone Investment Value

The Foregone Investment Value was calculated based on the construction estimate, engineering and regulatory costs. The Forgone Investment Value sometimes referred to as interest during construction, is typically considered in estimating the total capital cost of a proposed project. Throughout the construction period, funds are withdrawn from the economy to support the construction process. These allocated funds are therefore not available during the construction period for alternative investment opportunities that would provide net economic returns. A discount rate of 6 percent was assumed for this adjustment.

A construction period of five years was assumed for the project. For cost allocation purposes, cost of proposed storage facilities construction is assumed as follows.

Year 1: Land Acquisition Cost plus 15 percent Conveyance Facilities and Levee Improvements Costs
Year 2: 20 percent Conveyance Facilities and Levee Improvement Costs
Year 3: 25 percent Conveyance Facilities and Levee Improvement Costs
Year 4: 20 percent Conveyance Facilities and Levee Improvement Costs
Year 5: 20 percent Conveyance Facilities and Levee Improvement Costs

Forgone Investment Values are shown in Table 7.1.

Table 7.1: Forgone Investment Value Adjustment (Millions of 2003 Dollars)

Project Total Construction Costs *	Years to Construct	Adjustment (Year 4)	Adjustment (Year 3)	Adjustment (Year 2)	Adjustment (Year 1)	Adjustment (Year 0)	Total Adjustment
522	5	36.3	19.9	16.1	6.3	-	78.6

* Does not include mobilization cost

7.3.3 Annual Cost Development

The annual cost is the sum of the three elements: (1) the capital recovery cost, (2) property tax loss in-lieu property tax payments for loss of agriculture, and (3) the recurring annual costs. The first element includes the amortized total capital cost. The second element includes the loss of revenues due to loss of agricultural lands and in-lieu payment. The third element includes operation and maintenance costs as well as energy costs incurred for the project operations.

- Capital Recovery - Annualized capital costs were developed for each of the proposed projects. This is based on the total capital costs amortized over a 50-year period with an assumed discount rate of 6 percent.
- In-lieu property tax payments
- Recurring Annual Operation and Maintenance Costs. These costs include the following items:
  - Embankment maintenance.
  - Intake and outlet structures maintenance including pumping stations, gate units, siphons and fish screens for both, reservoir and habitat islands.
  - Pumping energy costs.
  - Seepage control systems maintenance and monitoring.
  - Water quality monitoring.
  - Environmental monitoring including wildlife and habitat monitoring.

Annual cost of development for In-Delta storage is given in Table 7.2.

Table 7.2: Total Capital and Equivalent Annual Cost Development (2003 $ million)

Total Project Cost	Forgone Investment Adjustment	Total Capital Cost	Annual Capital Cost	Annual O&M Cost	Equivalent Annual Cost
A	B	C	D	E	F
		A+B			D+E
774.4	78.6	853.0	54.1	5.9	60.0

7.4 Assessment of Project Benefits

7.4.1 General

To demonstrate the potential value of benefits the In-Delta Storage project might provide, DWR conducted a preliminary assessment using one of the sample operational scenarios described in Chapter 3. It should be stressed that this is only one possible scenario -- potential beneficiaries have not endorsed this or any other project alternative. Moreover, as described earlier, DWR needs additional assistance from economic experts and potential beneficiaries in reviewing the assumptions and procedures used in this analysis before finalizing this assessment. Project benefits included in the economic evaluation are quantified as follows:

- Additional SWP/CVP System Exports for urban and agricultural use including Joint Point of Diversion
- Contribution to meet CVPIA South of Delta Refuges
- Environmental Water Account
- Ecosystem Restoration Program
- Groundwater Recharge
- Flood Risk Reduction
- Levee Maintenance Cost Reduction
- Recreation

Project benefits described in qualitative terms are:

- wildlife habitat improvements;
- interim banking for water transfers storage;
- seismic stability;
- value of water quality improvements; and
- operational flexibility

7.4.2 Urban and Agricultural Water Supply Benefits

To estimate the urban and agricultural water supply economic benefits two models were used. An urban economic evaluation was performed using the Least-Cost Planning Simulation Model (LCPSIM) to determine benefits for the San Francisco Bay and South Coast Regions while the agricultural evaluation was preformed using the Central Valley Production Model (CVPM). The economic assumptions, evaluation methodologies, and study results are discussed in this chapter. In the example scenarios presented in this report, SWP and CVP water users were assumed to be project participants and the primary recipients of In-Delta Storage water supply benefits. Water supply benefits were allocated based on future expected water demands for these water users.

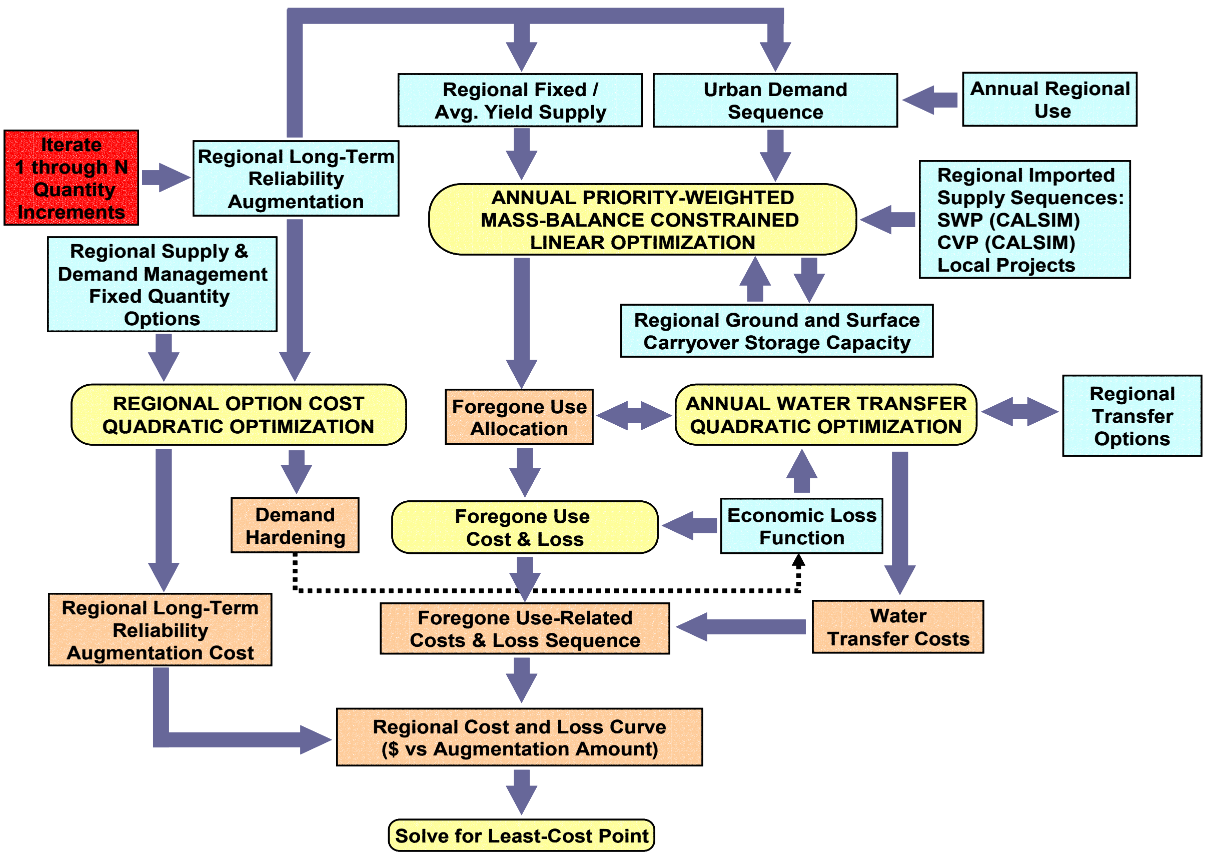


Figure 7.1: Conceptual Diagram of LCPSIM Urban Economic Model

7.4.2.1 Urban Benefits with LCPSIM Model

The logic involved in determining the urban benefits with the LCPSIM model is shown in Figure 7.1. Details of this model are presented in DWR Draft Report on Economic Analysis January 2004. As mentioned in Section 7.2, Methodology, and also as shown in Figure 7.1 Conceptual Diagram of LCPSIM Urban Economic Model, the CALSIM model output is input to the LCPSIM Model. The LCPSIM model goes through a number of analytical procedures to make decisions on allocating deliveries for a particular use. **During this process LCPSIM makes assumptions on the cost and**

availability of other regional options, and depending upon these assumptions, reallocation of deliveries may occur. To show this procedure of changing deliveries from initial allocation to final allocation, values in brackets are given for the South Coast Sample Scenario 2. The following is a step by step process for a decision on allocation by the LCPSIM Model.

- Benefits in relation to base deliveries include 2020 impacts on shortage related costs and losses and on the economic justification for adding additional local reliability from the available water use efficiency options (e.g., water recycling). The benefits of any alternative are determined by the change in total avoided costs and losses: shortage-related and related to the use of regional water use efficiency options.
- Within the South Coast and the San Francisco Bay Regions, the necessary capacity and policies needed to move available supplies among urban users to mitigate any localized shortage-related economic impacts caused by disparities in supply availability are assumed to be in place in 2020.
- The conservation options used in LCPSIM are beyond those expected to be implemented by 2020 under the urban Best Management Practices MOU.
- Regionally, the San Francisco Bay Region is expected to be at a relatively high level of reliability in 2020 after the assumed adoption of economically justified local water conservation and supply augmentation measures in the context of the assumed availability of local carryover storage. Consequently, SWP deliveries available under contract and interruptible deliveries for the San Francisco Bay Region that were not of net economic value to the region were assumed to be available to augment SWP South Coast Region urban deliveries.
- Additional SWP deliveries made to the San Joaquin Valley based on identified demand are assumed to be available to recharge available groundwater storage to be used by the south of the Delta water users under arrangements made with San Joaquin Valley water districts though the in-lieu groundwater semi-tropic storage.
- The availability and cost of the local regional options and availability of local carryover storage were assumed. The unallocated San Francisco Bay regional deliveries were added to the SWP contract supplies (including interruptible) and in lieu San Joaquin Valley groundwater storage supplies. This quantity (43 TAF in Sample Scenario 2) then became available for SWP urban use. After considering the availability and cost of regional options, 16.8 TAF was allocated for South Coast supplies. The supplies not allocated to the South Coast Region (26.2 TAF) were returned to augment SWP agricultural deliveries and recharge groundwater storage. This transformation from initial contract deliveries to final decision deliveries is shown below.

Initial SWP deliveries to be available for urban use	43.0 TAF
Delivery transferred from urban use to agricultural use	-26.2 TAF
Delivery accepted by LCPSIM for South Coast and other urban use	16.8 TAF
Delivery transferred from urban use to agricultural use	26.2 TAF
Additional urban delivery transferred to agricultural use	- 5.0 TAF
Net surplus delivery available for groundwater recharge	21.2 TAF

Initial SWP agricultural delivery	66.3 TAF
Additional urban delivery transferred to agricultural use	5.0 TAF
Delivery accepted by agricultural economic model	71.3 TAF
CVPIA Deliveries	14.6 TAF

Total of all deliveries for Benefits Analyses for Sample Scenario 2 = 16.8+21.2+71.3+14.6
= 123.9 TAF

The final urban and agricultural deliveries by LCPSIM used in benefits calculation are shown in Table No's 7.3 and 7.5. Note that under the assumptions used in this preliminary analysis, of the 43 TAF available for delivery to the South Coast Region, only 16.8 TAF was used. Other assumptions regarding the demand for future supplies and the availability and cost of other regional options might result in higher utilization of the water supplies available from In-Delta Storage and increase the estimate of value of benefits produced by the project.

- The incremental unallocated deliveries produced by the project were assumed to augment CVP agricultural deliveries.
- SWP deliveries driven by the banking targets in excess of the south of the Delta San Joaquin Valley banking use are assumed to be available for groundwater management in the San Joaquin Valley.
- Supplies available to, but not delivered for SWP urban use generated by in-Delta storage can be retained for CVPIA refuges water or can be credited to CVP for agricultural uses. For this study, the deliveries were credited to CVP agricultural users. This logic is meant to model one potential outcome of market based future water allocation negotiations between urban and agricultural users (in this case, an unconstrained "free-market" bookend.)
- Although the implementation of urban water conservation measures reduce the frequency and magnitude of shortages, demand hardening effects are assumed to cause an increase in economic losses when water shortages do occur. Because of the increased efficiency with which water is being used and the already implemented conservation measures (assumed to be less costly than the remaining conservation options) no longer available for shortage management, the value of new supply is therefore increased during shortage events.
- Reliability benefits for the Central Coast Region, an area not covered by the LCPSIM model, was interpolated from the results produced by LCPSIM for the South Coast Region.
- Benefits of in-Delta storage to urban users of SWP supplies in the San Joaquin Valley are based on the cost of existing local groundwater operations.
- Benefits of in-Delta storage to urban users of SWP supplies in the South Lahontan Region are based on project cost studies for applications submitted for Proposition 13 grants for groundwater storage projects.

A summary of the resulting preliminary assessment of urban water supply deliveries and benefits is shown in Table 7.3 and 7.4. A sensitivity analysis of potential variations in deliveries and benefits is presented in Section 7.4.7.

Table 7.3: Summary of Urban Water Supply Deliveries

Benefit Category	Scenario 2 (Study 2) Annual Water Supply Improvement (TAF)		Scenario 3 (Study 3) Annual Water Supply Improvement (TAF)		Scenario 4 (Study 4) Annual Water Supply Improvement (TAF)	
	Dry Period	Long-term Average	Dry Period	Long-term Average	Dry Period	Long-term Average
SF Bay Region	2.0	1.1	2.0	1.0	1.6	1.0
South Coast Region	24.9	6.4	22.3	17.3	13.3	5.2
Central Coast Region	0.9	1.3	0.8	1.3	0.6	0.9
San Joaquin Valley	1.2	2.6	1.1	2.5	0.6	1.8
Other Urban	3.6	5.4	3.4	5.3	2.4	3.9
Total Urban Supply Benefits	32.6	16.8	29.6	27.4	18.5	12.8

Table 7.4: Urban Water Supply Economic Benefits for Sample Scenarios

(2003 Dollars)

Benefit Category	($1,000)		
	Scenario 2 (Study 2)	Scenario 3 (Study 3)	Scenario 4 (Study 4)
SF Bay Region[1]	$224	$220	$123
South Coast Region[1]	$14,723	$13,621	$8,887
Central Coast Region	$428	$422	$317
San Joaquin Valley	$286	$275	$198
Other Urban	$1,080	$1,060	$780
Total	$16,741	$15,598	$10,305

[1]Includes water market transfers from San Joaquin Valley agricultural use to the SF Bay and South Coast Region urban use

7.4.2.2 Agricultural Benefits with CVPM Model

CVPM logic is shown in Figure 7.2. Detailed information on model application is presented in the DWR Draft Report on Economic Analysis.

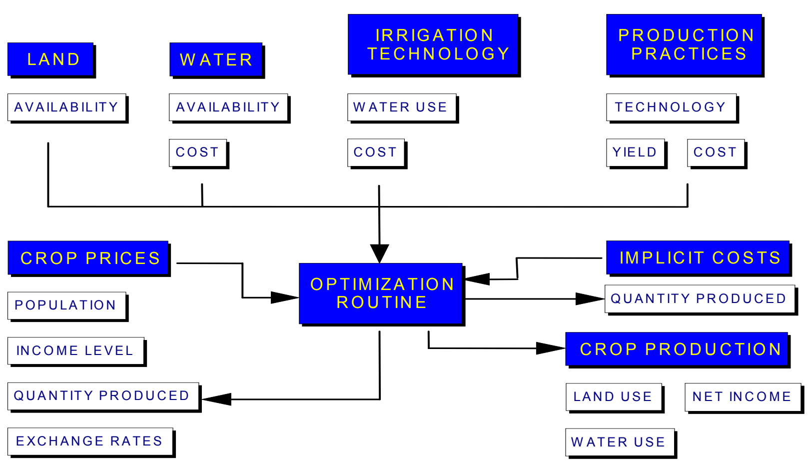


Figure 7.2: CVPM Agricultural Economics Model Logic

Assumptions used in economic analysis are as follows.

- Both short-run and long-run responses to changes in water resource conditions will be evaluated. The purpose of the long-run analysis is to estimate average economic conditions after farmers have made long-term adjustments to changes in supply availability and economic conditions. The purpose of the short-run analysis is to estimate acreage, crop mix, and water use during above and below average hydrologic events, given farmers' best possible responses to the temporary situation.
- The potential sources for agricultural water in each region are identified as CVP water service contract supply, CVP water rights and exchange supply, SWP supply, local surface supply, and groundwater.
- In the base case (i.e., no action alternative), unallocated interruptible and unallocated contract SWP urban deliveries are allocated to San Joaquin Valley SWP and CVP agricultural contractors in proportion to their deliveries under their respective contracts.
- The additional unallocated interruptible and unallocated contract SWP urban deliveries produced by the project are used to augment CVP agricultural deliveries.
- To reflect the reasonable (and conservative) assumption that planted acreage would not be based on interruptible deliveries because of planting decision constraints, planted acreage is held to the amounts which resulted from the evaluation of contract deliveries. In this manner, only reductions in local agricultural ground water pumping costs due to the in-lieu surface supply would be the benefit of the interruptible deliveries.

Agricultural benefits allocated to SWP and CVP are given in Tables 7.5 and 7.6.

The agricultural water supply deliveries are shown in Table 7.5:

Table 7.5: Summary of Agricultural Water Supply Deliveries

Benefit Category	Scenario 2 (Study 2)		Scenario 3 (Study 3)		Scenario 4 (Study 4)	
	Annual Water Supply Improvement (TAF)		Annual Water Supply Improvement (TAF)		Annual Water Supply Improvement (TAF)	
	Dry Period	Long-term Average	Dry Period	Long-term Average	Dry Period	Long-term Average
Contract Supply						
SWP	13.3	19.3	12.6	18.7	8.2	12.5
CVP	6.9	52.6	5.4	31.5	5.4	33.2
Total	20.2	71.9	18.0	50.2	13.6	45.7
SWP A21 Supply	-1.7	-0.6	-1.6	-0.6	-0.7	1.1
SJV Sales (Transfers) to SF Bay Region	0.1	0.0	0.1	0.0	0.1	0.0
SJV Sales (Transfers) to South Coast Region	0.0	0.0	0.0	0.0	0.0	0.0
Total	18.6	71.3	16.5	49.6	13.0	46.8

Shown in Table 7.6 is a summary of the agricultural economic benefits described above.

Table 7.6: Summary of Agricultural Benefits for Sample Scenarios
(2003 Dollars)

Benefit Category	($1,000) Scenario 2 (Study 2)	Scenario 3 (Study 3)	Scenario 4 (Study 4)
SWP & CVP Supply[1]	$4,100	$2,958	$2,655
Value Received From Water Market	$2	$2	$3
Total	$4,102	$2,960	$2,658

[1]Includes urban supplies reallocated from South Coast Region urban use to San Joaquin Valley agricultural use and water market transfers from San Joaquin Valley agricultural use to the SF Bay and South Coast Region urban use

7.4.3 Estimated Benefits of Other Water Supplies

Additional potential water supply benefits are summarized in Table 7.8 and include CVPIA Level 4 Refuge deliveries, the Ecosystem Restoration Program, additional protections for fisheries in the Delta through the EWA, and deliveries to the Kern Water Bank for improving San Joaquin Valley groundwater management. Further details on these other benefits are given in the following sections.

7.4.3.1 CVPIA Level 4 Refuge Supply

In-Delta Storage could provide water for supplies (in addition to Level 2 refuge supply) to meet Level 4 refuge demand if Delta export facilities have available capacity and thus releases could be made to benefit CVPIA. It would protect, restore, and enhance fish, wildlife, and associated habitats in the Central Valley with additional water supply for refuges. This CVPIA use could also be considered as system-wide use and could assist in improving the operational flexibility of the CVP and achieving a reasonable balance among competing demands for use of CVP water, including the requirements of fish and wildlife, agriculture, municipal and industrial, and power contractors.

For this study, CVPIA refuge water supply will be considered as a benefit to the CVP. The supply is thereby valued as an avoided cost to CVP agricultural users of the refuge diversions no longer required, about $60 per acre foot.

7.4.3.2 Environmental Water Account (EWA)

EWA water deliveries would be considered as make up water for any export reductions when SWP and CVP pumping is curtailed for specific actions in the Delta during the year. In-Delta Storage Project could provide water needed to support the EWA program, enhancing the EWA agencies ability to respond to real-time fisheries needs and would eliminate the need to purchase a substantial portion of water needed by EWA each year. South of the Delta, where the water is more valuable to the program, the value based on recent experience is about $210 per acre-foot.

7.4.3.3 Ecosystem Restoration Program (ERP) Delta Flows

Releases from In-Delta Storage could help meet spring pulse flows proposed in the ERP. Project operations could also provide additional water quality and aquatic habitat improvements by releasing carryover water saved in islands storage. This water could be released at strategic times during fall and winter for environmental benefit. The avoided cost of water purchases for this purpose was estimated to be about $180 per acre foot.

7.4.3.4 Groundwater Recharge

Deliveries to the San Joaquin Valley can be used to help mitigate groundwater management problems through recharge. These deliveries are valued at the average alternative cost of agricultural groundwater pumping in the San Joaquin Valley, about $55 per acre foot.

7.4.3.5 Summary of Estimated Benefits of Other Water Supplies

The other supply deliveries are shown in Table 7.7.

Table 7.7: Summary of Other Water Supply Deliveries

Benefit Category	Scenario 2 (Study 2)		Scenario 3 (Study 3)		Scenario 4 (Study 4)	
	Annual Water Supply Improvement		Annual Water Supply Improvement		Annual Water Supply Improvement	
	Dry Period	Long-term Average	Dry Period	Long-term Average	Dry Period	Long-term Average
Groundwater Recharge	4.5	21.1	1.4	10.1	1.4	12.3
Enviornmental Water Account			10.3	31.2	9.7	36.7
Ecosystem Restoration Program					14.9	15.7
CVPIA Level 4 Refuges	5.5	14.6	3.4	11.0	3.4	11.7
Total	10.0	35.7	15.1	52.3	29.4	76.4

The economic benefits assigned to the quantified water supplies are shown in Table 7.8:

Table 7.8: Summary of Additional Quantified Water Supply Benefits
(2003 Dollars)

Benefit Category	($1,000)		
	Scenario 2 (Study 2)	Scenario 3 (Study 3)	Scenario 4 (Study 4)
Groundwater Recharge	$991	$534	$648
Environmental Water Account	$0	$6,552	$7,707
Ecosystem Restoration Program	$0	$0	$2,826
CVPIA Level 4 Refuges	$876	$693	$702
Total	$1,867	$7,779	$11,883

7.4.4 Other Quantified Benefits

7.4.4.1 Recreational Benefits

The proposed reservoir and habitat islands will provide increased public recreation in the Delta. Recreational opportunities will include hunting, fishing, hiking, biking, and interpretative experiences and have a positive effect on local economy. The economic benefits assigned to recreation are shown in Table 7.9:

Table 7.9: Estimated Recreation Benefits
(2003 Dollars)

Category	Visitor Days	New User Factor	New Users	Unit Day Benefit $/Day[1]	Total Benefit ($1,000)
Hunting	9,019	100%	9,019	$24.18	$218
Fishing	9,600	20%	1,920	$16.93	$33
Hiking/Biking	3,000	20%	600	$16.93	$10
Intrepretation	30,000	20%	6,000	$16.93	$102
Boating	186,240	10%	18,624	$16.93	$315
Total	237,859		36,163		$678

[1]US Army Corps of Engineers Economic Guidance Memorandum 01_01, Unit Day Values for Recreation, Fiscal Year 2001 (indexed for inflation)

7.4.4.2 Avoided Levee Maintenance Cost

Current levee maintenance costs for Webb Tract and Bacon Island will be replaced by the maintenance included in the cost of In-Delta storage. This avoided cost is an added project benefit. These costs are based upon the average maintenance expenditures for the period 1990 to 2001 and amount to $711,000.

7.4.4.3 Flooding Risk Benefits

The benefits of reducing the probability of incurring the economic costs of levee breach events on Webb Tract and Bacon Island under conditions with and without the proposed project were evaluated by the URS Corporation, "In-Delta Storage Program Risk Analysis", June 2003. The benefits were estimated to be $324,000 annually. The significant costs evaluated included:

- Breach Repair
- Fish Entrainment Recovery
- Fish Mitigation
- Loss of Water Supply
- Marina Repair

7.4.5 Benefits Described in Qualitative Terms

7.4.5.1 Delta Benefits

7.4.5.1.1 Contribution to Water Quality Management Plan (D 1641) Delta Requirements

Although there are no additional D1641 requirements imposed on In-Delta Storage operations, coordination with the SWP/CVP is required under the CUWA/DW agreement. With this coordination both the SWP and CVP would benefit, because the In-Delta Storage Project could make water available for D1641 more quickly and efficiently than releases from upstream reservoirs.

7.4.5.1.2 Aquatic Resources

Fish species will benefit in a variety of ways. State of the art fish screens are included in the In-Delta Storage proposal. Storing water in the Delta near the State and federal water project pumping facilities improves the ability of the projects to time pumping to avoid affecting at-risk fish species. By storing surplus flows in the Delta, diversions from the Trinity and American River basins can be reduced and carryover storage in upstream reservoirs increased, allowing improved flows for fisheries on both rivers. Additional ecosystem benefits will accrue from improved environmental water quality. Frequent circulation or exchange of water within the island reservoirs may release algae and zooplankton, a food source for fish.

7.4.5.2 Carryover Storage

The carryover storage is available for use by the projects for south of the Delta supplies and water quality improvements or environmental instream uses on the Sacramento and Feather rivers. Folsom carryover can be used for flow improvements in the American River. Any carryover storage in upstream SWP and CVP reservoirs could be transferred to In-Delta storage on interim basis during times when Banks and Tracy Pumping Plants do not have a pumping capacity to transfer water to the South.

7.4.5.3 Wildlife Habitat Improvements

Wildlife habitats will be improved and protected by developing terrestrial, aquatic and wildlife-friendly agricultural habitats on Holland Tract and Bouldin Island.

7.4.5.4 Interim Banking for Water Transfers Storage

North to South negotiated water transfers between SWP and CVP users could also make use of the In-Delta storage for interim parking. As negotiated amounts of transfer depend on many factors including carryover storage, available supplies and storage space, this would require future detailed work for estimation in terms of monetary value.

Recent instances of south of the Delta users having completed negotiations on purchase but could not find interim storage identifies need for storage space like being provided by the In-Delta Storage Project.

7.4.5.5 Seismic Stability Benefits

The current designs do not provide for assured non-failure of the proposed storage facilities during strong seismic loading. Instead, the risk of failures (or breaches) of the proposed reservoirs are considered in the current planning and design as an acceptable level of risk. Such breaches would be significantly less costly to repair than typical failures of “existing” Delta levees, as embankment widths are greater and differential water elevations between the reservoirs and adjacent sloughs are greatly reduced during periods of reservoir storage. Also important is the reduction of the consequences of potential failures during low flow periods in the sloughs (summer and fall). During these periods, the reservoirs would be full or at least partially full, so that potential failures would not result in drawing water into the failed islands, resulting in increased salinity levels. Instead, fresh water would be released, with beneficial impact on salinity levels into what would be a damaged overall Delta system, and minimization of scour damage would facilitate rapid repair of potential failures on the two project islands.

These are potentially very significant project benefits, but their value is difficult to assess, and depends to some extent on the actions that may be taken to reduce seismic vulnerability of appurtenant islands, levees, and other Delta facilities.

7.4.5.6 Water Quality Improvements

7.4.5.6.1 Drinking Water Quality

Storage in the Delta would provide additional water to meet drinking water requirements under Water Quality Control Plan (SWRCB D1641) obligations and any future restrictions. In-Delta Storage will be used to push salinity downstream during summer and fall months to improve water quality conditions in Delta channels and at the urban export pumps. Better water quality at the export pumps will result in drinking water treatment costs savings.

7.4.5.6.2 Environmental Water Quality

Storage in the Delta would provide additional water to meet environmental water quality and flow requirements under SWRCB D1641 obligations and any future restrictions. Water saved in upstream reservoirs by using In Delta storage water to meet D1614 requirements is available for other uses including water quality and ecosystem purposes.

7.4.5.7 Value of Operational Flexibility

In-Delta storage will increase operational flexibility of SWP and CVP systems due to availability of stored surplus flows, capability of the In-Delta Storage Project to provide water at different times and its strategic location to respond to emergencies in the Delta. Multipurpose type operations are possible as demonstrated in Chapter 3 on Operations.

7.4.6 Summary of Project Benefits for Sample Scenarios

Descriptions of estimated project water supply related and other benefits covered in Sections 7.4.1 to 7.4.5 are summarized in Table 7.10.

Table 7.10: Economic Benefits Summary for Sample Scenarios
(2003 Dollars)

Benefit Category	($1,000)		
	Scenario 2 (Study 2)	**Scenario 3 (Study 3)**	**Scenario 4 (Study 4)**
Urban	$16,741	$15,598	$10,305
Agricultural	$4,102	$2,960	$2,658
Other	$1,867	$7,779	$11,883
Subtotal Supply Benefits	$22,710	$26,337	$24,846
Recreation	$678	$678	$678
Flooding Risk Reduction	$324	$324	$324
Avoided Levee Maintenance	$711	$711	$711
Total	$24,423	$28,050	$26,559

7.4.7 Potential Benefits Sensitivity Analysis

A sensitivity analysis was performed to determine the impact of variations in various assumptions and procedures used in the urban economic models for assessing the potential benefits. The LCPSIM Model input is based partially on B160-98 assessment of the available regional management options or regional water use efficiency options (e.g., conservation, wastewater recycling, groundwater reclamation etc.) to meet shortages and partially on estimates developed during the CALFED Programmatic EIS/EIR process.

The Example Scenarios economic analyses details are described in previous sections. For Sample Scenario 2, the preliminary assessment of the value annual water supply benefits the In-Delta Storage Project would produce in the South Coast Region is approximately $14 million. As an example case, the urban economic model application for the South Coast Region under Sample Scenario 2 was further analyzed in the sensitivity analysis. Costs of water shortages were assessed for different levels of cost and availability of other regional management options. Figure 7.3 shows the variations in supply from the regional options, costs of supplying local water to meet shortages, the contribution of the In-Delta Storage Project and variations in the potential benefits.

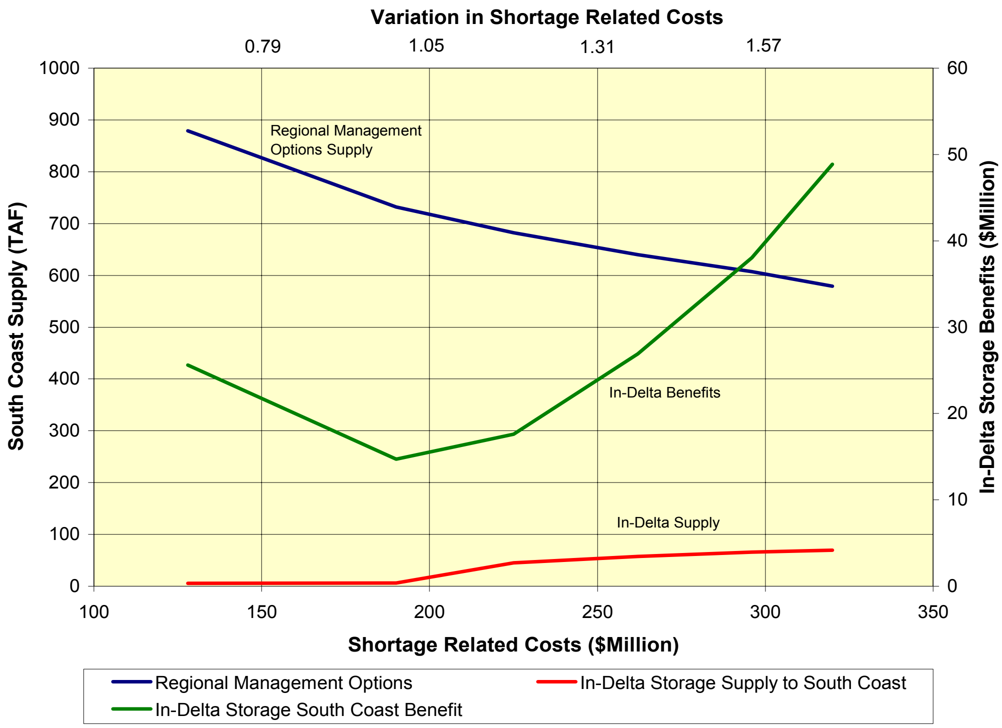


Figure 7.3: Sensitivity Analysis for South Coast Management Options Assumptions

This analysis indicate that there is a significant variation in South Coast benefits, and the results of the economic analyses are very sensitive to assumptions about the cost and availability of regional water use efficiency options. If the assumptions are unreasonably optimistic about cost and/or availability of the regional options, the value of the In-Delta Storage Project will be understated. Another source of sensitivity is the assumption of how much value water users place on water system reliability. If this value is unreasonably low, the value of the In-Delta Storage Project will again be understated.

The economic analyses models used to categorize benefits should be considered as one of many project feasibility indicators. Benefits may change with refinements in analyses and economic expert consultations are required to improve assumptions in the economic models. Details of this analysis are presented in the DWR *Draft Report on Economic Analysis, January 2004*.

7.5 Delta Economic Impacts

The economic impact analysis was designed to identify potential gains and losses to the area local to the proposed project stemming from changes in the economy of the area due to the existence of the project. For this purpose, input-output models designed to identify economic linkages in the local economy were employed. These linkages exist because a change in the level of any economic activity in one sector of the economy affects the level of activity of those sectors of the economy that provide it with goods and services. Farmers, for example, depend on the output of tractor manufacturers and dealers and, depending upon the crop, custom services for harvesting. Those providing custom services for harvesting, in turn, depend upon the output of harvest equipment manufacturers, equipment repair services and fuel suppliers and so on.

The effects generated by input-output models are classified as direct (e.g., cut in farm production), indirect (e.g., reduced need for custom harvesting services), and induced. The induced effects arise from the change in income due to the direct and indirect effects. This income change affects the overall level of consumption of goods and services.

For the purposes of the impact analysis, the linkages are evaluated only in so far as they affect local economic activity. The impact on equipment manufacturers in other parts of California or other states is not included, for example. Also outside of the scope of this impact analysis are the same types of economic effects, which occur in the areas benefiting from the additional water supply reliability provided by the proposed project.

Changes in local economic activity evaluated in this section arise from:
- loss of crop production;
- operations and maintenance of the proposed project facilities (including recreation facilities); and
- additional recreation days produced by the proposed project.

The impact numbers generated for these evaluations represent the sum of the direct, indirect, and induced economic effects and were developed using a MIG IMPLAN model set up for Contra Costa and San Joaquin counties. The income effects shown are for employee compensation and proprietor's income effects only.

7.5.1 Loss of Crop Production

Table 7.11 shows the change in agricultural crop acres due to the proposed project. The calculation of the net change includes accounting for the Habitat Management Program that is assumed to be implemented under the with project conditions.

Table 7.11: Estimated Net Change in Crop Acres Due To Proposed Project

Crops	Existing Acres					HMP Acres					Net Change				
	Webb	Holland	Bouldin	Bacon	Total	Webb	Holland	Bouldin	Bacon	Total	Webb	Holland	Bouldin	Bacon	Total
Harvested															
Alfalfa							935	1,925		2,860		935	1,925		2,860
Corn (field)	3,250		3,200	2,200	8,650						-3,250		-3,200	-2,200	-8,650
Safflower				800	800		170			170		170		-800	-630
Small grains	900		1,600	500	3,000						-900		-1,600	-500	-3,000
Sunflowers				1,200	1,200									-1,200	-1,200
Tomatoes (Fresh)			150		150								-150		-150
Pasture		2,500			2,500							-2,500			-2,500
Unharvested															
Corn							106	339		445		106	339		445
Small Grains							595	1,225		1,820		595	1,225		1,820
Total	4,150	2,500	4,950	4,700	16,300		1,806	3,489		5,295	-4,150	-694	-1,461	-4,700	-11,005

Table 7.12 shows the estimated local employment and employee and proprietor income and employment impacts of the loss of that production on each of the affected Delta islands as a consequence of the proposed project.

Table 7.12: Local Employment and Employee and Proprietor Income and Employment Effects from Change in Agricultural Production

(2003 Dollars)

Crops	Income ($1,000)					Jobs				
	Webb	Holland	Bouldin	Bacon	Total	Webb	Holland	Bouldin	Bacon	Total
Harvested										
Alfalfa		$1,357	$2,862		$4,219		68.9	145.3		214
Corn (field)	-$1,378		-$1,787	-$1,228	-$4,393	-56.9		-73.5	-50.5	-181
Safflower		$56		-$369	-$313		2.4		-15.5	-13
Small grains	-$205		-$625	-$195	-$1,025	-9.4		-28.7	-9.0	-47
Sunflowers				-$514	-$514				-21.6	-22
Tomatoes (Fresh)			-$832		-$832			-25.3		-25
Pasture		-$320			-$320		-16.6			-17
Unharvested										
Corn		$33	$147		$179		1.3	5.9		7
Small Grains		$97	$373		$470		4.5	17.3		22
Total	-$1,583	$1,223	$138	-$2,307	-$2,529	-66	61	41	-97	-61

The crop income effects shown are the result of indexing 1997 crop prices. Based on a weighted average, prices received in 1997 resulted in about a 20% percent higher income compared to the income from average prices received for the period 1997 to 2001 for the corn, small grain, and oilseed crops. To the extent the 1997 may be an unusually high income year for the purposes of forecasting future impacts for these crops, income and the economic impacts arising from that crop income may be overstated.

The lower average income would be unlikely to result in lower expenditures on farm operations, however. The crops would still need basically the same inputs to be produced and harvested. More likely, farm operators and land owners would have less income as compared to the 1997 situation.

Helping to offset this lower of income to farm operators and land owners from market sales is the income from government crop support payments. When crop market receipts are lower, the income from government payments has historically been higher. Crops which would be affected by the In-Delta Project which are presently eligible for federal farm program payments include wheat, corn, safflower, and sunflower seeds. Forecasting the nature, size, or even the existence of future federal farm programs, the programs' impact on crop market prices, and the participation by growers on the affected islands is problematical.

Taken into account in Table 7.12 is the fact that the grain and hay and corn crops which would remain on Bouldin and Holland would no longer be harvested under the proposed habitat management program. The expenditures on harvesting will no longer be incurred and thus contribute to income and employment impacts in the local area.

Not taken into account in Table 7.12 is the full effect of the loss of crop production on those activities related to the storage and processing of the crops produced after they leave the farm. To the extent that these activities take place in the local area, or to extent that local storage facilities and processors cannot substitute other crops, this represents a loss not captured in this evaluation. How much of this impact would fall on the local area is difficult to estimate, however. The impact of the loss of hauling is included, however, and is assumed to be a local impact.

This analysis was based on crop surveys done by the Department in 1995 and 1996, information on more recent cropping provided by Delta Wetlands staff, and the proposed Habitat Management Plans for Bouldin Island and Holland Tract. Price and yield data from the County Agricultural Commissioner's Reports were also used.

7.5.2 Gains from Operations and Maintenance of the Proposed Facilities

Operation and maintenance expenditures for the water supply and recreation facilities will have a positive effect on local employment and income. Table 7.13 shows the indirect, and induced economic gains for each alternative. The recreation plans recommended by CH2M HILL for scenarios are assumed to be implemented. Table 7.14 reflects the fact that employment and income current levee maintenance activity will be forgone, however, when that activity is superceded by the proposed project.

Table 7.13: Local Employment and Employee and Proprietor Income Effects from Operation and Maintenance Expenditures
(2003 Dollars)

Expenditure Category	Expenditures ($1,000)	Generated	
		Employment (FTE)	Income ($1,000)
Maintenance	$4,307	113	$4,604
Energy	$956	3	$200
Operating Staff Compensation	$610	13	$944
Total	$5,873	128	$5,747

Table 7.14: Local Employment and Employee and Proprietor Income Effects from the Discontinuation of Current Levee Maintenance Expenditures
(2003 Dollars)

Expenditure Category	Expenditures ($1,000)	Generated	
		Employment (FTE)	Income ($1,000)
Maintenance	$711	19	$760

7.5.3 Recreation Gains

The additional days of recreation generated by the proposed project will also have a positive effect on local employment and income. This arises from expenditures by recreationists in the local area. Table 7.15 shows the indirect, and induced economic recreational gains for each alternative. The increase in recreation will likely generate about 35 FTE jobs and contribute about $900,000 in employee and proprietor income to the local economy.

It was assumed for this study that the all of the hunting days induced by the public hunting opportunity provided by the proposed project will be new days with the exception of the existing hunting on the affected islands (see above.) "New" days are those which are not defined by visits which would have been made elsewhere in the local area or just represent an enhanced experience for visitors who would be in the same location anyway. In both of these cases, additional local expenditures are not generated.

Table 7.15: Local Employment and Employee and Proprietor Income Effects of Recreation Expenditures
(2003 Dollars)

Activity Type	Visitor Days[1]	Expenditures[2]	New User Factor	Total Regional Expenditures		Generated	
						Employment	Income
				Factor[3]	($1000)	(Persons)	($1000)
Hunting	9,019	$41.05	89%	50%	$164	8	$205
Fishing	9,600	$43.28	20%	50%	$42	2	$52
Hiking/Biking	3,000	$41.05	20%	50%	$12	1	$15
Intrepretation	30,000	$41.05	20%	50%	$123	6	$153
Boat Visit Days	186,240	$41.05	10%	50%	$382	19	$476
Total	237,859				$724	35	$901

[1]Based on CH2MHill Recreational Options Technical Memo (Nov 30, 2001)
[2]Based on 1996 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (U.S. Department of the Interior
[3]Estimated from Sacramento-San Joaquin Delta Recreation Survey (1995)

In contrast, it was assumed that only twenty percent of the days generated by fishing, hiking and biking, and wildlife interpretation and only ten percent of the boating days will be new days. It was also assumed that trip expenditures within the Delta area and, therefore, affecting the local economy, were about one-half of the total trip expenditures. Not counted were expenditures outside the Delta but in nearby areas that would still be of significant benefit to the local economy.

Visitor days were obtained from the November 2001 Recreational Options Technical Memorandum prepared by CH2M HILL. California expenditure numbers were adopted from the 1996 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation report done by the U.S. Department of the Interior. The percentage of expenditures made within the Delta was developed from information in the 1995 Sacramento-San Joaquin Delta Recreation Survey done for the California Department.

7.5.4 Net Local Employment and Income Effects

Table 7.16 shows the net effect on the local economy of the loss of agricultural production on the affected islands, the additional recreation expected from the proposed project, and the operations and maintenance activities which will be required to operate the water supply facilities as well as the recreation facilities. The In-Delta Storage Project will have minimal adverse impact because agricultural losses are substantially offset by increased recreation and maintenance jobs and income.

Table 7.16: Net Local Employment and Employee and Proprietor Income Effects
(2003 Dollars)

Effect Category	Employment (FTE)	Income ($1,000)
Agricultural Production	-61	-$2,529
Current Levee Maintenance	-19	-$760
Recreation	35	$901
Operations and Maintenance	128	$5,747
Net Effect	83	$3,359

7.5.5 Net Local Sales Tax Revenue Effects

Shown in Table 7.17 are the estimated overall net positive fiscal effects on local public revenues from sales taxes. These values were estimated using the IMPLAN model to link the changes in local expenditures to local retail trade activity. One percent of the retail sales were assumed to be returned to the counties as sales tax revenues.

Table 7.17: Net Local Sales Tax Revenue Effects
(2003 Dollars)

Effect Category	Taxes ($1,000)
Agricultural Production	-$4
Current Levee Maintenance	-$2
Recreation	$7
Operations and Maintenance	$9
Net Effect	$11

7.6 Summary

DWR estimates the equivalent annual cost for the In-Delta Storage Project at approximately $60 million. The Department's preliminary benefits analysis conservatively values the annual water supply benefits the project would produce at approximately $23 to 26 million. An additional $2 million in annual benefits would be associated with the recreation, flood damage reduction and avoided levee maintenance provided by the project. The results of the economic analysis are very sensitive to assumptions about the cost and availability of regional water use efficiency options (e.g., conservation, wastewater recycling, groundwater reclamation etc.). If the assumptions are unreasonably optimistic about the cost or availability of the regional options, the value of the In-Delta Storage Project will be understated. Another source of sensitivity is the assumption of how much value water users place on water system reliability. If this value is unreasonably low, the value of the In-Delta Storage Project will again be understated.

DWR needs additional assistance from economic experts and potential beneficiaries in reviewing the assumptions and procedures used in this analysis before finalizing this assessment. In addition, many of the benefits such as operational flexibility, water quality improvements, wildlife and habitat improvements and seismic stability, have not yet been quantified. Before total project benefits and cost can be compared, value must be assigned to these benefits. All potential project participants, including the State must use judgment to estimate the value of the benefits the In-Delta Storage Project might provide and determine if those benefits justify the project costs. The Department will work with the Bay-Delta Public Advisory Committee and the California Bay-Delta Authority to gather input from interested parties before completing this benefits assessment.

Any future steps on the In-Delta Storage Investigation should also include refinement of the operational analyses that drive the benefits assessment. This refinement should consider uncertainty in future operations at the State Water Project's Banks Pumping Plant, the OCAP, and other important CALFED Program actions that are being studied simultaneously.

Chapter 8: POLICY AND LEGAL ISSUES

8.1 General

Policy and legal issues related to the review process to make a decision on the acceptance of the State Feasibility Study results by CALFED agencies and further steps to be taken to prepare subsequent EIR/EIS are explained in this Chapter.

Several legal issues arise with respect to implementing the project. These issues include: (1) what CEQA and NEPA document should the CALFED implementing agency prepare for implementing a CALFED In-Delta Storage Project, (2) what other permits or legal requirements might be needed before the In-Delta Project could be implemented, (3) potential liability of implementing the project and (4) determining if DWR has statutory authority to implement an In-Delta Storage Project. The following discussion addresses these legal issues. Throughout the discussion, it is assumed that CALFED agencies would implement the In-Delta Project, if feasible, as the implementing and funding agencies for in-Delta storage under the CALFED Implementation MOU.

8.2 Review Process

As shown in Figure 8.1, the following is the order of the In-Delta Storage Program State Feasibility Study reports review process.

1. Internal agency reviews by DWR and USBR.
2. Engineering investigations draft reports review by IBC completed in May 2003.
3. CBDA Science Panel review in August 2003.
4. Public Reviews in February 2004.
5. BDPAC WSS review of the State Feasibility Study draft reports in February/March 2004.
6. BDPAC and CBDA reviews of the final State Feasibility Study reports in March/April 2004.

The CALFED Science Panel completed a written review of the May 2002 Planning Study reports in October 2002. Science Panel reviewed the June 2003 State Feasibility Study and supporting documents in July 2003 and a Public Science Workshop was held in August 2003. DWR received Science panel Workshop Report on December 23, 2003. CALFED Science Panel is providing guidance to meet the short-term and long-term objectives for resolving the water quality issues.

The DWR IBC completed its initial review of the 2001 Planning Study in December 2001. Recommendations of the engineering studies reviewed by IBC in May 2003 have been included in the Draft Engineering Investigations Summary July 2003 Report and the Draft Summary Report.

8.3 Permitting Process

In order to comply with the CEQA and NEPA, Delta Wetlands (DW) Properties Inc., the original proponents of the project prepared an EIR/EIS. DW Properties submitted a Draft EIR in 1995 to the SWRCB pursuant to water rights filings. The EIR was revised in July 2000 and a water right permit was issued in February 2001. An EIS was prepared in July 2001 and USACE issued a 404 permit in March 2002.

CALFED's Guide to Regulatory Compliance for Implementing CALFED projects recommended that CEQA/NEPA compliance with should be integrated with other regulatory requirements such as: NHPA, Federal Endangered Species Act (FESA), Fish and Wildlife Coordination Act (FWCA), California Endangered Species Act (CESA) and Section 404 of the Clean Water Act (CWA).

DW has obtained nearly all permits and agreements needed for implementing its project as described in its EIR. These permits were obtained as part of the SWRCB approval of the water rights application and EIR. DW permits for the project include: SWRCB water rights permit, FESA biological opinions, CESA permit, Programmatic Agreement for protection of historical and cultural resources, and CWA 401 certification. If Reclamation/DWR were to acquire or be responsible for implementing the project, it would be responsible for complying with the project permits. DW and Reclamation/DWR would need to notify the permitting agencies that DWR has acquired the permits as part of the project.

Therefore, for the permits already obtained for the DW Project, DWR will need to review each permit with the permitting agency to determine if new conditions may be necessary before implementing the project. A detailed list of regulatory agencies and permits required to undertake various activities is given in Table 8.1

In addition to permits, DW agreed to several settlement agreements with other agencies. These settlement agreements specifically apply to any subsequent owners or operators of the DW Project. DWR would be required to comply with these agreements, such as the East Bay Municipal Utility District (EBMUD) Agreement to protect fish on the Mokelumne River and the CUWA agreement to protect drinking water quality from DW discharges. DWR may also need to enter into additional agreements to address issues not resolved by DW.

The existing permits may require amendments if the project conditions change. In the case of the ESA biological opinions, Reclamation/DWR may need to reinitiate consultation on changes that may affect endangered species. In the case of the National Marine and Fisheries Service (NMFS) opinion for the DW Project, NMFS did not include incidental take authorization for the rediversion of DW discharges by other parties, such as rediversion at the CVP and SWP Delta facilities. (NMFS 1997 and transmittal letter from NMFS to USACE (May 8, 1997).

If Reclamation/DWR propose a modified In-Delta Storage Project, it is likely Reclamation/DWR would need to file a petition with the SWRCB addressing any changes in points of diversion, place of use, or purpose of use. The need to petition the SWRCB will depend on the type of change needed and whether the change may be allowed under the existing permit conditions. Changes in proposed mitigation, such as implementation of the HMP on Bouldin Island or Holland Tract would require returning to the SWRCB to modify the permit conditions. Even if Reclamation/DWR did not make changes to the DW Project, it is possible that further SWRCB action might be needed to address unanticipated problems, such as with water quality or fish impacts. The SWRCB has retained continuing authority to impose additional terms as needed for drinking water quality protection, levee design and seepage control systems, fish protections, and protection of beneficial uses in general (D-1643 conditions 9 and 35).

8.4 Legal Issues

8.4.1 CEQA Documentation Required for In-Delta Storage Project

The SWRCB and USACE prepared an EIR/EIS for the DW Project, through Jones & Stokes and Associates. The SWRCB was required to prepare the CEQA document before approving DW's water rights application and the USACE required the EIS to approve a 404 application for construction of the project. On February 15, 2001, SWRCB certified the Final DW Project EIR and adopted Decision 1643 approving DW's water rights application and issuing an order stating terms and conditions of the water rights permit. On February 16, SWRCB filed a Notice of Determination giving notice of adoption of the final EIR and the water rights decision.

CEQA regulations provide that DWR may assume the lead agency status of the In-Delta Project and CEQA document as the next agency with responsibility to undertake or approve the project. The SWRCB was lead agency but completed its grant of necessary approvals for the project and this approval need not be reopened by DWR (CCR, Title 14 Sections 15162).

Pursuant to NEPA regulations, Federal agencies may adopt a federal draft or a final EIS or portions thereof if the EIS is adequate (Code of Federal Regulations, Title 40, Section 1506.3). If the original action described in the EIS is substantially the same as the proposed action, the agency adopting the EIS is not required to recirculate the document. If the proposed action and the action described in the EIS are not substantially the same, then the adopting agency must treat the document as draft and recirculate it.

Project changes include operational considerations in order to integrate In-Delta operations with SWP and CVP operations. Moreover, the EIR and the biological opinions for the DW Project do not address the impacts of exporting the water at the SWP/CVP Delta pumping facilities. Because impacts of the specific use of the water have not been analyzed and disclosed in an environmental document, additional analysis is needed pursuant to CEQA and NEPA on this aspect of the project.

The following discussion on CEQA requirements assumes that the DW Project would require modification and therefore may require additional documentation. Even with this assumption, DWR could use the DW Project EIR by adding to it and preparing a supplemental EIR. Or, DWR could prepare a subsequent EIR containing new information and referencing the DW EIR to make use of existing information and analysis. In addition, although not discussed below, NEPA issues would be similar to those of CEQA. A federal lead agency for an In-Delta Project, may consider revising the draft EIS to satisfy any project changes that may be necessary for implementation.

The type of additional CEQA documentation that would be required as DW Project required modifications will depend on the type of environmental impact the project changes might cause. If DWR determines through an initial study of the recommended changes that these would not cause any new potential impacts, no further document would be needed. (Laurel Heights Improvement Association v. Regents of University of California (1993) 6 Cal. 4th 1112 (Laurel Heights II); River

Valley Preservation Project v. Metropolitan Transit Development Board (1995) 37 Cal. App. 4th 154; Benton v. Board of Supervisors of Napa County (1991) 226 Cal. App. 3d 1467.) Where recommended project modifications may cause potential environmental impacts, DWR could prepare three types of additional CEQA documentation: a subsequent EIR, a supplement to the DW EIR, or an addendum to the DW EIR. These three options are discussed below.

DWR must prepare a "subsequent EIR" if DWR determines there are substantial project changes, or circumstances with respect to the project substantially change, or new information of substantial importance is available, and these changes cause significant new impacts not previously disclosed in the DW EIR. A subsequent EIR would be subject to the same procedural and public participation requirements of a project EIR. (PRC Section 21166 and CCR Title 14, Section 15162.) DWR could attempt to confine the scope of the subsequent EIR, but the public and decision-makers may use the subsequent EIR to question the overall project. DWR could choose to rewrite the entire EIR or could prepare a more limited document addressing the changes and incorporating by reference the prior EIR, which could be attached to the new document.

DWR could prepare a "supplement" to the EIR if the substantial changes, as described above, constitute only minor additions or changes. The supplemental EIR need contain only information necessary to addresses the changes and make the EIR adequate. The supplemental EIR must be noticed and circulated for public review the same as a draft EIR, but neither a notice of preparation nor a response to comments document is required.

Finally, DWR could prepare an "addendum" to the DW EIR if proposed changes are minor technical changes or additions and do not cause a significant impact. An addendum is sometimes prepared where the project has not yet been approved or to alter mitigation measures that does not change environmental impacts. An addendum does not need to be circulated for agency or public review.

In addition to the possible additional CEQA documents that DWR may need to prepare, DWR could link the CEQA document for the in-Delta storage project to the CALFED Programmatic EIR/EIS as a "tiered" document. As a tiered document, the DW Project EIR/EIS would incorporate the analysis of regional effects, cumulative impacts, and broad alternatives that apply to the program as a whole. The project EIR could also include any applicable mitigation measures of the Programmatic EIR/EIS that might be required for cumulative impacts. For example, any significant impacts to agriculture for loss of land that have not been mitigated could be addressed through the CALFED Programmatic mitigation proposal (See Appendix A of CALFED ROD).

Although many formats of CEQA documentation are possible, DWR should choose the document that will provide the most complete analysis of the potential environmental impacts in order to withstand judicial scrutiny. DWR experience with CEQA documentation indicates that the more complete the initial environmental documentation, less time and money will be spent over the long-term on such costs as litigation or dispute resolution.

A conservative recommendation based on the recommended project changes discussed in the State Feasibility Study documents would be for DWR to assume lead agency status of the SWRCB EIR and prepare a subsequent EIR that addresses any changes in the project, changes in circumstances, and new information on the project since it was approved by the SWRCB.

8.4.2 DWR Authority to Construct In-Delta Storage Project

The Burns-Porter Act (Water Code Section 12930 et seq.) and the Central Valley Project Act (Water Code Section 11100 et seq.) (together "Acts") provide authority for DWR to acquire land and construct an in-Delta storage facility. The Acts grant DWR broad authority to develop and construct the SWP in conjunction with the CVP.

The Acts grant DWR authority to construct and maintain a State Water Resources Development System, also known as the SWP, composed of a variety of water facilities. "State Water Facilities" are defined as:

> "Master levees, control structures, channel improvements, and appurtenant facilities in the Sacramento-San Joaquin Delta for water conservation, water supply in the Delta, transfer of water across the Delta, flood and salinity control, and related functions." Water Code Section 12934(d)(3).

The proposed CALFED In-Delta Storage Project would store and distribute water for possible uses of "supply," "conservation," and "salinity control" through a variety of "levee" systems and "control structures." As defined by the Acts, these uses and facilities come within DWR's existing authority to construct the SWP. The In-Delta Storage Project also could be considered an "appurtenant" facility of DWR's SWP because it would be physically connected and operationally integrated with, and thus appurtenant to the SWP.

Under other sections of the Water Code, DWR has authority to acquire and construct additional facilities as part of the SWP, "including such other additional facilities as the department deems necessary and desirable to meet local needs, including, but not restricted to, flood control, and to augment the supplies of water in the Sacramento-San Joaquin Delta…" (Water Code § 12931). This discretionary authority is also recognized in another section of the Act which authorizes funding for construction of additional facilities the department determines necessary to meet local needs and to augment supplies of water in the Sacramento-San Joaquin Delta from multiple purpose dams, reservoirs, aqueducts and appurtenant works (Water Code Section 12938).

The California Supreme Court in *Metropolitan Water Dist of So. Cal. v. Marquardt* (1963) 59 Cal.2d 159, 28 Cal.Rptr. 724, recognized DWR's discretionary authority to determine necessary additional facilities pursuant to Water Code Sections 12931 and 12938. The Court concluded that the facilities authorized in these sections are in addition to those enumerated in Section 12934(d) and include such other facilities as DWR deems necessary and desirable to meet local needs or to augment the supplies of water in the Delta. The In-Delta Storage Project could reasonably be considered an additional facility as described within the statute and case law. The law supports the conclusion that DWR has existing authority to acquire lands and construct In-Delta Storage Project.

8.4.3 Other Permits or Legal Requirements Needed for Implementation

DW has obtained many permits and agreements for purposes of implementation. These permits were obtained as part of the SWRCB approval of the water rights application and EIR. DW permits for the project include: SWRCB water rights permit, FESA biological opinions, CESA permit, Programmatic Agreement for protection of historical and cultural resources, CWA 401 certification, and 404 COE Permit. If Reclamation/DWR were to acquire or be responsible for implementing the project, it would be responsible for complying with the project permits. DW and Reclamation/DWR would need to notify the permitting agencies that DWR has acquired the permits as part of the project.

Under the existing permits, however, if project conditions change, the permits may require amendments. In the case of the ESA biological opinions, Reclamation/DWR may need to reinitiate consultation on changes that may affect endangered species. In the case of the NMFS opinion for the DW Project, NMFS did not include incidental take authorization for the rediversion of DW discharges by other parties, such as rediversion at the CVP and SWP Delta facilities. (NMFS 1997 and transmittal letter from NMFS to U.S. Army Corps (May 8, 1997). Therefore, for the permits already obtained for the DW Project, DWR will need to review each permit with the appropriate permitting agency to determine if new conditions may be necessary before implementing the project or if some of the conditions would not apply to a State/federal owned project.

With respect to the water rights permit for the DW Project Islands, DWR or Reclamation will need to consider if the In-Delta Storage Project that is proposed will use the water as permitted within the terms and conditions of Decision 1643. If Reclamation/DWR acquire the DW property, Reclamation/DWR would have the right to use the water appurtenant to those lands pursuant to established rights. California law presumes that water rights pass with the transfer of land unless expressly excepted (See CCR Title 23, Section 833.) Assuming that DW would not reserve the water right to itself, as prior owner of land that is sold, DW would be required to file a statement of the transfer with the SWRCB stating the name and address of the new owner and the application number of the water right (CCR Title 23, Section 831).

The DW water rights obtained for the storage project include the right to divert at several points of diversion from adjacent channels onto Webb Tract and Bacon Island and the right to redivert the water at three export locations, the CVP Tracy Pumping Plant, the SWP Banks Pumping Plant, and/or the Contra Costa Canal Pumping Plant. The permit requires that the project construction be completed and water use begun by December 31, 2011. The authorized place of use of the water is the CVP and SWP service areas and the Bay-Delta estuary (D-1643 conditions 1 – 5.) The permit includes many requirements and constraints on use of the water, such as specified seasons of diversion, limits of amounts diverted, compliance with water quality and fish protection criteria, and reporting and monitoring requirements. The permit prohibits filling the storage reservoirs above MSL until the permittee can demonstrate to the SWRCB's Chief of Division of Water Rights that the water can be wheeled and that it has contracted with at least one entity for delivery of the water (D-1643 conditions 21 and 34(b)).

No new water rights were obtained for Bouldin Island and Holland Tract. These islands will use existing water rights for implementing the HMP proposed as mitigation for construction and operation of the reservoir islands. The water rights for Webb and Bacon Islands, however, are conditioned on the continued operation and management of the habitat on Bouldin and Holland pursuant to HMP (D-1643 condition 25(g)).

If Reclamation/DWR were to implement the DW Project as described in the water rights permit, they probably would not need to request any further action by the SWRCB. However, as DWR is proposing a modified In-Delta Storage Project, it is likely Reclamation/DWR would need to file a petition with the SWRCB addressing any changes in points of diversion, place of use, or purpose of use. The need to petition the SWRCB will depend on the type of change needed and whether the change may be allowed under the existing permit conditions. Changes in proposed mitigation, such as implementation of the HMP on Bouldin Island or Holland Tract would require returning to the SWRCB to modify the permit conditions. Even if Reclamation/DWR did not make changes to the DW Project, it is possible that further SWRCB action might be needed to address unanticipated problems, such as with water quality or fish impacts. The SWRCB has retained continuing authority to impose additional terms as needed for drinking water quality protection, levee design and seepage control systems, fish protections, and protection of beneficial uses in general (D-1643 conditions 9 and 35).

In addition to permits, DW agreed to several settlement agreements with other agencies. These settlement agreements specifically apply to any subsequent owners or operators of the DW Project. DWR would be required to comply with these agreements, such as the EBMUD Agreement to protect fish on the Mokelumne River and the CUWA agreement to protect drinking water quality from DW discharges. DWR may also need to enter into additional agreements to address issues not resolved by DW. For example, PG&E has concern that the project may impact its two gas pipelines from flooding of Bacon Island. The DW water rights permit from the SWRCB requires the permittee to obtain an agreement with PG&E or court judgment stating that the permittee has a right to construct a reservoir and fill it with water (D-1643 condition 22). Therefore, prior to operating the storage project, DWR must obtain an agreement from PG&E to resolve any conflicts regarding potential project impacts and responsibility to mitigate such impacts. If DWR and PG&E cannot reach agreement, a court proceeding might resolve the issue. As with all issues surrounding potential conflicts with the construction and operation of the in-Delta storage proposal, the problems are fact specific and will require detailed analysis of the proposed storage project and the rights of the affected entity, such as PG&E.

8.4.4 Potential Liability of Implementing Project

Reclamation/DWR could purchase the DW Project land and construct the project. As landowner and operator, Reclamation /DWR would be subject to potential damage claims as permitted by law. Such potential claims could include permit violations or harm to persons or property resulting from negligent operations of the project. Such potential liability would be similar to the potential DWR experiences as operator and owner of lands and facilities associated with the SWP. An advantage to purchasing the project is that Reclamation/DWR would have maximum control over design and construction and could construct a project that it believes would minimize future risk of liability associated with operations. The disadvantage is that Reclamation/DWR would be subject to costs of claims arising from the project under its control.

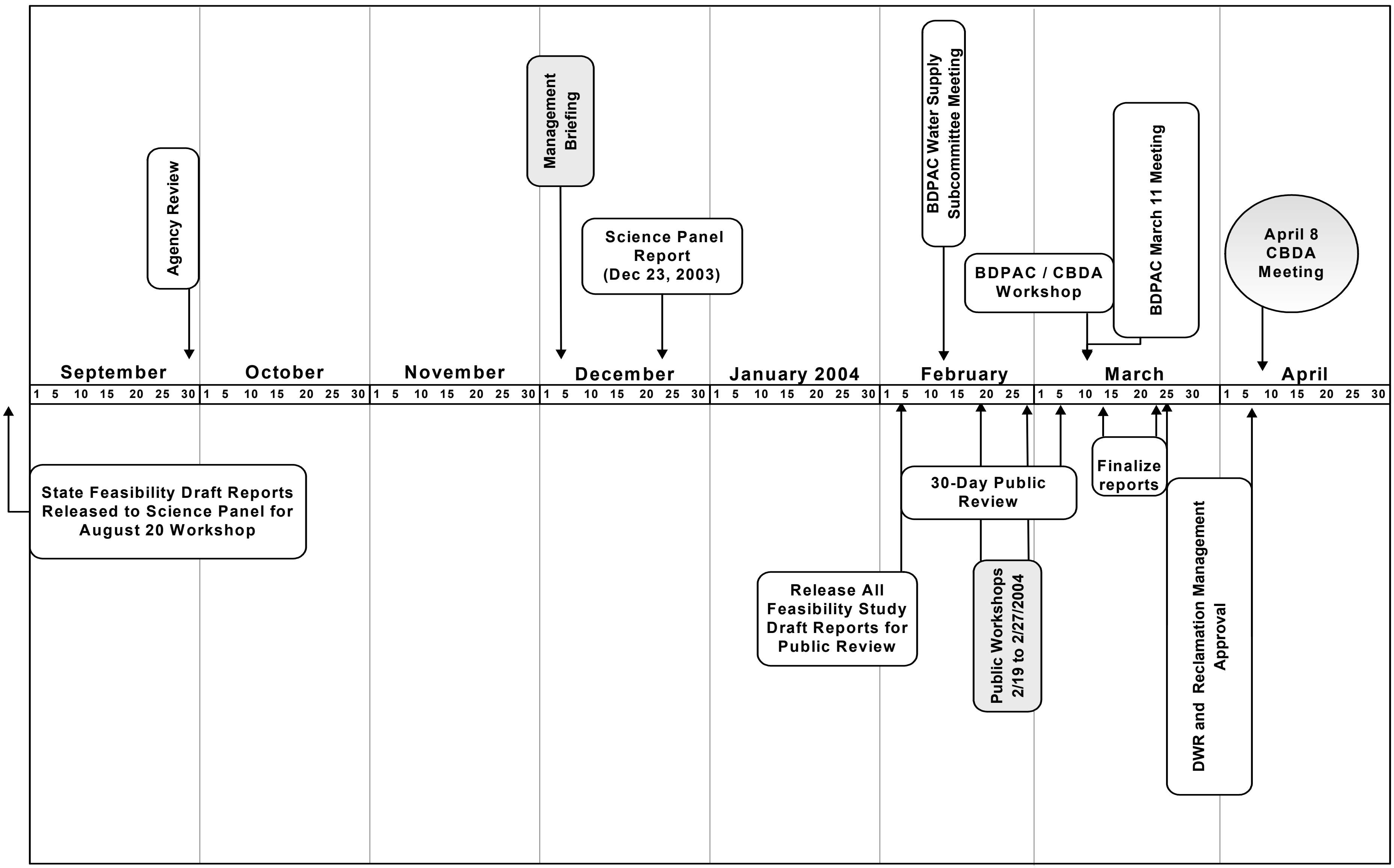
The potential for liability associated with hazardous material on the property, however, could be reduced by requiring that DW take responsibility for site cleanup before Reclamation/DWR acquire the land. Prior to acquisition, Reclamation/DWR could have a hazardous materials site inspection performed to diligently investigate if any hazardous contaminants are present. DW would be required to remove any contamination as a condition of acquisition.

Table 8.1: Permits and Approvals Required For In-Delta Project

Agency and Regulation	Required Authorization	Project Activity
FEDERAL **U. S. Army Corps of Engineers**		
Clean Water Act (Section 404) EPA Section 404(b)(1) Guidelines	The USACE permit for discharge of dredged or fill material into waters of the United States, including wetlands	Construction of levees, reservoir, inlet and outlet works, and conveyance facilities
Rivers and Harbors Act of 1899 (Sec 10)	The USACE permit for activities in or affecting navigable waters	Construction of levees, intakes, pumps and fish screens and recreational facilities
U.S. Bureau of Reclamation		
Petition to amend water rights	Reclamation petitions SWRCB to modify rights to allow changes in diversion location quantity or rate	Diversion of Delta water exceeding existing water rights
Contract amendments or approvals	Reclamation amends contracts with water agencies and COA Agreement with the State	Modifications to CVP System, and changes in operation and maintenance and service area
U.S. Fish and Wildlife Service **National Marine Fisheries Service**		
Endangered Species Act (Section 7) Fish and Wildlife Coordination Act	Federal agencies consultation and approvals from USFWS and NMFS required for projects which may affect listed or proposed endangered or threatened species or critical habitat	Project implementation and activities affecting control and modification of surface waters
STATE		
California Dept. of Fish and Game		
Stream Alteration Agreement	DFG agreements with agencies proposing changes to rivers, streams or lakes	Construction of levees, reservoir, inlet and outlet works, and conveyance facilities
California Dept. of Water Resources		
Approval to use DWR Facilities	DWR evaluates and gives consent to agency plans to modify or tie into DWR facilities	Tie into Clifton Court Forebay and modifications to SWP Delta exports
Approval of plans and specifications	DSOD grants approval to plans and specifications	Design and construction of an In-Delta Project
Notice of completion, actual	DSOD evaluates safety of newly	Storage of project water

cost statement and approval to impound water	constructed or enlarged reservoir and grants approval to initiate storage operations	
The Reclamation Board		
Encroachment Permit on project levees	The Reclamation Board reviews and grants approval to activities affecting the USACE flood control	Construction in designated USACE floodways and installing works affecting flood control projects
State Water Resources Control Board		
Permit to appropriate water rights and/or amendment to existing water rights	SWRCB issues permit to allow appropriation of water and grants approval to divert water to storage and to change purpose of use	Additional diversions and changes in points of diversion, storage and water uses for additional demands
Water quality certification pursuant to Section 401 of the Clean Water Act	SWRCB certifies that the applicant complies with the State's water quality standards	Construction of levees, reservoir, inlet and outlet and conveyance facilities
Regional Water Quality Control Board		
Waiver from discharge requirements	RWQCB's approval for project waste discharge into surface waters and projects affecting groundwater quality	Any earth-moving activities, discharge from dewatering into storm drains and creeks and wastewater from conveyance cleaning operations
State Lands Commission		
Dredging Permit and lease for encroachment on State lands	State Lands Commission issues a permit for dredging and deposit of material on State lands	Activities requiring use of State owned-lands for construction and siting of project facilities
California Dept. of Transportation		
Encroachment Permit	Caltrans issues encroachment permit for projects affecting right-of way of State-owned roadways	Conveyance facility crossings
Regional and Local Agencies and Utilities		
Encroachment and crossing permits	Counties, Cities, Irrigation Districts, Utility Companies and Railway entities issue permits	Construction of facilities affecting drainage, utilities and railway structures

Figure 8.1: In-Delta Storage Program Review Process



APPENDIX A - ABBREVIATIONS AND ACRONYMS

AFRP	Anadromous Fish Restoration Program
CALFED	California Federal Bay-Delta Program
CALSIM	California Simulation Model
CCWD	Contra Costa Water District
CESA	California Endangered Species Act
CEQA	California Environmental Quality Act
CPT	Cone Penetrometer Test
CUWA	California Urban Water Agencies
CVP	Central Valley Project
CVPIA	Central Valley Improvement Act
CVPM	Central Valley Production Model
DBW	Department of Boating and Waterways
DFG	Department of Fish and Game
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DOE	Division of Engineering
DBP	Disinfection byproducts
DPC	Delta Protection Commission
DSOD	Division of Safety of Dams
DW	Delta Wetlands
DWR	Department of Water Resources
EBMUD	East Bay Municipal District
EC	electrical conductivity
E/I	Export/inflow
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
ESA	Endangered Species Act
EWA	Environmental Water Account
FMW	Fall Mid-Water Trawl
FOC	Final Operations Criteria
HMP	Habitat Management Plan
ISI	Integrated Storage Investigations
LCPSIM	Least-Cost Planning Simulation Model
maf	million acre-feet
mg/L	milligrams per liter
MILP	mixed integer linear programming
MOU	memorandum of understanding
MSL	mean sea level
MWQI	Municipal Water Quality Investigations Program
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMFS	National Marine and Fisheries Service
O&M	Operations and Maintenance
ppm	Parts per million

ppt	Parts per thousand
PEIS	Programmatic Environmental Impact Statement
PG&E	Pacific Gas and Electric
Reclamation	U.S. Bureau of Reclamation
ROD	Record of Decision
SMARTS	Special Multipurpose Research Technology Station
SWP	State Water Project
SWRCB	State Water Resources Control Board
TAF	thousand acre-feet
TTHM	total trihalomethanes
TOC	total organic carbon
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
VAMP	Vernalis Adaptive Management Plan
WQMP	Water Quality Management Plan

APPENDIX B - Review: In-Delta Storage Program CALFED Science Review Public Workshop Report (December 23, 2003)

Introduction

The In-Delta Storage Review Panel convened by the CALFED Science Program has reviewed documents and met with In-Delta Storage (IDS) Program Staff for the purpose of evaluating the scientific quality and technical soundness of the draft feasibility reports. The template for the project evaluated is the Delta Wetlands Project as modified and refined by DWR project staff and their consultants.

The Review Panel recognizes the importance of water supply and drinking water quality to the California Bay-Delta Authority (CBDA) and the future of California. It is not the Review Panel's role to recommend whether or not to move forward with in-delta storage options. Rather, this Panel provides this report to decision-makers within CBDA and local, state and federal agencies to inform them regarding the science used in the studies, and the level of uncertainty surrounding the scientific and technical aspects of the proposed project.

The Review Panel's general charge from the Science Program

The panel was instructed as follows: "The key policy question for DWR and CALFED is whether the Delta Wetlands Project and other in-Delta storage options considered in the reports are technically feasible based on the reports' assessments. We do not expect the science review to address this question directly, but your input should help policy makers understand the scientific underpinning available to address this question. It is important to articulate both the strengths and limits of that underpinning. With regard to the studies that were conducted to determine feasibility, please help policy makers understand: Have those studies used approaches at the state of the science? Are the experiments, field studies and analyses credible? Are there alternative approaches that might provide more credible results? Are there scientific issues that are potentially important to evaluating feasibility that remain unaddressed? Have the studies articulated uncertainties and assumptions in a balanced manner? Are there studies in the literature in similar circumstances that could be brought to bear to address the issue of feasibility? In short, would the scientific community view these studies as valid, at the state of the science, and useful to helping managers address the complex questions surrounding operations, water quality and environmental issues of the in-delta storage question? If not, what else can be done in the short-term and the long-term?"

Previous Major Recommendations from Science Panel's Summary Review of 2002 Reports, August 2002 (see attached review)

Quantify and assess uncertainties: For almost all aspects of the work reviewed, the Panel recommended a quantitative assessment of uncertainties in experimentally determined or model parameters. The general lack of error estimation prevents a complete and reasonable assessment of the possible effects of the project thereby elevating the risk of any decision based on these assessments.

Develop a process-oriented conceptual model of the system: Another theme touched on by all reviewers was the need to develop a comprehensive, process-oriented conceptual model of the reservoir system, showing the processes and their linkages, both driving project operation and affected by project operation. Because of the complexity of the system within which the project is set, a series of nested conceptual models is recommended. The conceptual models should include quantitative information (including uncertainty) about fluxes and linkages and provide the framework for future data collection and modeling to further reduce uncertainty. The primary advantage of using a conceptual model that is frequently reexamined is a continuing directed focus on what is important to effectively evaluate project effects and yields. This type of integrative tool would underpin the more holistic, ecosystem based approach recommended by the panel.

Consider and assess potential mercury issues: The Panel noted the lack of any detailed attention to the potential mercury and methyl mercury problems in the proposed project. The proposed project will produce environmental conditions conducive to methyl mercury formation. The Panel recommended that the mercury issue be critically addressed.

Develop climate change and variability scenarios: The Panel recognized the limited incorporation of these important influences into their assessment. The Panel recommended the development of future scenarios of climate change and variability (e.g., precipitation and temperature regimes) that would provide a range of water availability conditions within which in-delta storage dynamics can be assessed.

Diffusion of dissolved organic carbon (DOC) from peat soils: Measurement of diffusive fluxes of DOC from reservoir soils using either intact soil cores or *in situ* mesocosms was recommended to obtain valuable information regarding contributions of DOC from the peat soils.

Modeling of DOC: As an alternative to the empirical, logistics/regression-equation approach to modeling DOC in the reservoir, development of a process-oriented model that takes into account pertinent processes affecting DOC, such as sediment-water flux, water column vertical diffusion and mixing, water column production and biogeochemical transformations of DOC, horizontal exchanges or flushing, etc., is suggested.

Modeling Seepage returns: The reviewers' recommended using a 3-D model for estimating seepage returns for the complex peat soil-reservoir system and emphasized the importance of understanding and incorporating the interactions between the reservoir surface water and the local and regional groundwater system into the model to better reflect the hydrologic complexities of the system. At least, seepage return flows and loads and their uncertainties need to be better quantified.

Vertical stratification and horizontal variability: Due to concern over the possibility of vertical temperature stratification (and horizontal variability) within the proposed reservoirs and possibly in adjacent channels, the Panel recommended that a three-dimensional hydrodynamic model be applied to the proposed reservoirs and adjacent channel environments and include components for heat flux and transport, wind-induced turbulent mixing and residual circulation, wetting and drying of computational cells, spatially variable bathymetry, and transport capabilities for embedded reactive constituents.

Modeling of dissolved oxygen (DO) and water temperature (T): The Panel recognized the importance of considering biological and biogeochemical processes, as well as taking into account vertical stratification and horizontal variability, in the modeling of DO and T. Thus, the recommendation for assessing and modeling these biological and physical processes and incorporating them into a three-dimensional model.

In addition to the above recommendations, the Panel recommended a series of ten tasks over a five-year timeline designed to reduce uncertainty about whether the project is likely to meet water quality criteria controlling operation, and provide a sound scientific basis for making a decision regarding project implementation (please see the attached review).

To expedite this process and meet the proposed timeline it was recommended that DWR make use of the best available expertise in the various fields of science and call upon in-house personnel, consultants, and both in- and out-of-state experts to move these Tasks to fruition on the proposed timeline. To accomplish this, it also was recommended that a Steering Committee of independent advisors (i.e., experts not directly involved in accomplishing any of the Tasks) be convened to advise DWR in the selection of study participants, to review draft reports, and recommend modifications of these Tasks and/or the timeline as appropriate.

Progress

The Review Panel recognizes the complexities of the system that the In-Delta Storage Program Staff is dealing with and recognizes the challenge and difficulties they faced in assessing the feasibility of this project, especially considering the time constraints imposed on them. The IDS Staff is commended for putting forth a tremendous effort in producing the feasibility reports.

The panel acknowledges the progress of the DWR IDS staff in responding to some of the panel's initial recommendations. First, the mismatch between modeled timescales and real-world operational and regulatory timescales has begun to be addressed with the modification of CALSIM and DSM2 to allow CALSIM to generate and pass to DSM2 daily operational information (previously, this was done on a monthly timestep). Second, a large step toward addressing the panel's concern over the reservoirs' stratification potential was taken in contracting with Flow Science, Inc. to apply the DYRESM model to the proposed reservoirs.

Remaining Major Issues

Quantifying uncertainty
Many simulations and calculations were performed to estimate the answers to specific questions like "What will the change in DOC at the Rock Slough Intake be under conditions similar to Water Year 1976-1991 if the reservoirs are built?" and "What is the expected change in SWP/CVP delivery with the reservoirs operating and several operational constraints in place?" Many well-established tools (DSM2, CALSIM) and field measurements have been invoked to generate answers to these questions, and the simulations run thus far have been instructive in learning about critical interactions between operations, hydrology, and water quality.

The Panel is concerned, however, that there is not just one possible answer to a particular question. Instead, there is a *range* of possible answers for any particular question. The reason for this range of answers is the ***error or uncertainty*** associated with every step in the calculation process. These errors include inherent inaccuracies and simplifying assumptions associated with individual numerical models, errors associated with field or laboratory measurements used as input to the models, uncertainty associated with empirical relationships between water quality parameters, and cumulative propagation of errors when models are used iteratively or in series. Uncertainty due to such errors is unavoidable, and it can be very small or very large compared to the magnitude of the answer. The error size relative to the size of the answer is really an answer to the question: "***How wrong can our answer be?"*** Without knowing this, we are unable to say whether the feasibility study or state of scientific knowledge is adequate for decision makers to reach a conclusion on whether the project is feasible.

The Panel sees quantitative estimation of uncertainty as one of the most critical and pervasive, though as yet inadequately addressed, issues related to this feasibility study. The DWR IDS team has conducted and presented a large amount of valuable work, but we still do not know how wrong the answers could be. For example, we are told that the change in SWP/CVP delivery with reservoirs operated with circulation and DOC constraints is 66 thousand acre feet (TAF) (if DOC growth rate is 0.24 g/m^2-d). But is that 66 TAF +/- 1 TAF or +/- 10 TAF or +/- 100 TAF? Such an uncertainty estimation would need to incorporate error associated with all steps in making that estimate. Information exists for quantifying the uncertainty associated with some calculation steps. For example, extensive validation of the DSM2 model was performed previously, including comparisons between model calculations and measurements of electrical conductivity (EC) and other variables. Errors could be quantified from such validation studies as one of the sources of error. Lack of error analysis and uncertainty estimation was a pervasive problem in the feasibility studies---it applies to DOC, disinfection byproduct precursors (DBPs), DO, temperature, mercury, EC, and storage/delivery estimates. We reiterate here that conceptual models---developed to identify and estimate the relative magnitudes of critical processes and rates---can be valuable tools in the estimation of uncertainty.

Modeling and Predicting DOC

We suggested that the IDS staff develop and apply a process-based conceptual model of carbon dynamics for the reservoir in our first review and reiterated our suggestions several times during the March 2003 meeting between selected Panel members and the IDS Staff. The Panel believes that the appropriate scientific approach to understanding and modeling the carbon dynamics in such a complex system is to use a conceptual model to help focus the key questions, hypotheses, and data gaps. This process should help prioritize their efforts, which, in turn, should help develop the pertinent information and knowledge to better assess the feasibility of the project, as well as improving the conceptual model of the system. We envision that the conceptual model could initially include quantitative information about fluxes and linkages between model compartments and their respective uncertainties. The model should be updated and refined as more data are collected.

In addition, development and application of mathematical models that quantitatively capture pertinent DOC processes (as suggested in the initial summary review) needs to replace the empirical "logistics/regression" modeling approach that does not account for the biogeochemical processes affecting carbon dynamics.

The consensus of the Panel is that the current mesocosm experiments do not effectively represent Delta organic carbon dynamics, and that the important biogeochemical processes are not distinguishable through this approach. The Panel sees the need for a new experimental approach that allows quantification of significant biogeochemical and physical processes separately, so that the relative magnitude of each process is determined. The Panel suggested that other approaches such as *in-situ* benthic flux chambers in existing Delta environments and process-specific microcosms in analogous environments and habitats be used to bound conditions. These types of approaches are essential to quantifying uncertainties.

Assessment of DOC dynamics needs to recognize that the quality of DOC can be as important as the quantity of DOC. In other words, DOC derived from different sources (e.g., peat soils, algae) and subjected to a variety of biogeochemical processes (e.g., microbial decomposition, photolysis) can have vastly different potentials to form DBPs in general and trihalomethanes (THMs) in particular. For example, the quantity of DOC diffusing from peat may be 5 times greater than algal contributions during late summer, but the type of DOC that decomposing algae produce may be 5 times more reactive with respect to the formation of THMs; thus contributions from both peat and algae would be significant and need to be considered. This example further emphasizes the need to distinguish processes, timing of reservoir release, and hydrodynamics within the reservoir and in the channel.

Further considerations that should be addressed in future assessments include:
Accounting for DOC production and dynamics under low reservoir water levels (< 4 ft.). Reoxidation of surface soils will undoubtedly occur under these conditions, especially in areas where soils are exposed to the atmosphere due to topographic irregularities. Wetting and drying of peat soils has been shown to cause enhanced production of available carbon that is mobilized upon rewetting.

The Panel has concerns regarding the current assessment of the contribution of DOC from seepage that is captured and reintroduced to the reservoir. Both seepage flows and associated DOC concentrations need to be critically reassessed, using possible ranges of expected flows and DOC concentrations to capture potential uncertainties of these estimates.

Three key uncertainty and conceptual issues plague the seepage estimates. First, what seepage return values were used in the reservoir water quality modeling? The July 2003 In-Delta Storage Program State Feasibility Study Draft Report on Water Quality stated that seepage losses and returns are 9.8 and 1.96 cubic feet per second (cfs) for Bacon and Webb, respectively. However, the URS modeling estimate for Webb is 8.3 cfs. Was 1.96 cfs was used in subsequent reservoir modeling? If so, why? Second, seepage modeling appears deficient in that there is a lack of uncertainty quantification in seepage return estimates and reservoir water quality modeling. The most recent 2002 URS modeling did not vary hydraulic conductivity values during sensitivity analysis and provided no range for seepage return volumes. However, using a similar modeling approach but including sensitivity analysis using a range of reasonable sand hydraulic conductivity values, the 2000 URS evaluation identified a potential 5 fold increase in seepage return volumes . Also, we find the two-dimensional model for estimating seepage to have over constrained boundary conditions and to not fully account for system variability and well to well interactions. There is a key need to quantify flow paths and travel times of high DOC pore water that certainly resides in shallow peat layers to seepage return pumps. This will enable estimation of DOC concentration changes over time in seepage pumps.

Lastly, uncertainty in predicted seepage rates and potential variability in DOC concentrations should be used to estimate the possible range of DOC loads to the reservoir due to seepage return pumping.

A "circulation" or "recirculation" operational model was proposed to lower the potential DOC content of waters stored in the reservoir islands. In this model, equal quantities of water were diverted from the channel to the reservoir and released from the reservoir to the channel. This model was not part of the initial proposal, but was developed to compensate for continuously increasing reservoir DOC concentrations that occurred if the water remained in the reservoirs for long periods of time.

The Panel had several concerns regarding the proposed circulation operational model. Among these concerns are the assumption that the reservoir are acting as a Continuously Stirred Tank Reactor, within which concentrations are uniform. The Panel's concern with this assumption is discussed below in the Horizontal Variability subsection of the Remaining Major Issues section.

Other concerns include the potential for recirculating discharged reservoir water high in DOC and whether this operational scheme is economic feasibility due to the potentially high cost of pumping. In addition, this proposed operational scheme has the potential for increasing loads (concentration x volume) of DOC, DBP precursors, and methyl mercury to Delta channel waters.

The Panel thought that these concerns were not adequately addressed and will require further assessment in the future.

Water Temperature
The Flow Science, Inc. report on stratification formation in reservoirs and relationships with adjacent channels was a positive step toward addressing stratification potential. This work also highlighted the criticality of meteorological forcing and data (especially windspeed), as well as the potentially large amount of spatial variability in meteorological forcing within the Delta. The panel recommends that meteorological stations be installed at the proposed reservoir sites to gather site specific data and reduce the level of uncertainty in DYRESM's projected stratification scenarios. This effort could be amplified by incorporating long-term estimates of changes in meteorological forcing (e.g. air temperature) due to climate change. We further recommend, depending on the results of amended DYRESM simulations, that stratification-sensitive water quality variables (e.g. organic carbon, dissolved oxygen, conductivity, etc.) and reservoir release constraints be investigated in a stratified or stratifiable context.

Dissolved Oxygen
Dissolved oxygen could be an important constraint on reservoir release; however, there are critical shortcomings in how DO has been treated thus far. First, DO was assumed to be 5 mg/l (or 6 mg/l, depending on where one looks in the reports) and artificially maintained at this level throughout the simulations. Given the constraints on release of reservoir water (cannot release if DO of stored water < 6 mg/l or if depresses channel water to <5 mg/l), it is not surprising that DO violations are not predicted. The panel does not understand this methodology and regards this as *specifying* DO as opposed to modeling DO. DO should be modeled freely as an unconstrained function of the sources

and sinks outlined in the Draft Report on Water Quality, Fig. 4.1. Otherwise, the "modeling" of DO in this study is not deemed useful or reliable.

Second, the Flow Science report on stratification indicated that, under some conditions, the reservoirs could become persistently temperature stratified. Such a situation could lead to low dissolved oxygen levels below the thermocline. Thus, reservoir DO dynamics should be studied in a thermally stratified context. Furthermore, Susan Paulson (Flow Science, Inc.) indicated that thermal stratification need not be present for DO to be stratified. Therefore, this possibility (of vertically variable DO in the absence of thermal stratification) should be looked into.

Third, the Panel recommends that biological oxygen demand (BOD) be considered in the assessment of oxygen dynamics in the reservoir system and channel water. BOD may be a better predictor of changes in oxygen concentrations when reservoir water is released into Delta channel waters.

Mercury
The Panel again emphasized the need to include a comprehensive assessment of potential methyl mercury production in the reservoirs, and noted the need for specialized expertise in mercury cycling, as well as for sampling and analyses of total and methyl mercury. Anticipated reservoir conditions of warm temperatures, elevated concentrations of DOC, and probable anoxic sediments are conducive to methylation of mercury. The Panel also noted the existing evidence of high rates of mercury methylation in wetlands in the Delta, as well at other wetland locations.

Climate Change
The panel understands that positive progress is being made in using CALSIM to investigate scenarios of drought and changes in the hydrograph (earlier peak flows) due to long-term climate change. It is unclear, however, what other projected changes are or will be accounted for. We recommend that sea level rise and changes in precipitation and air temperature should also be addressed on some level.

Horizontal Variability
The modeling work performed thus far has assumed that water quality variables and related processes will not vary in the horizontal dimension within reservoirs. In reality, variations in bathymetry, fetch, proximity to inflows/outflows and other factors could result in marked variability in three-dimensional transport and mixing, submergence/emergence of the sediment boundary, water clarity, temperature, generation and processing of organic carbon (e.g. phytoplankton, submerged and emergent aquatic vegetation, DOC, etc.), contaminants, and mediation of key processes by primary and secondary consumers. The assumption of horizontal homogeneity was a logical place to start in modeling the key processes and quantities. However, the panel believes horizontal variability is likely. Other nearby flooded island habitats subject to tidal mixing can exhibit substantial horizontal variability in quantities such as water temperature, chlorophyll *a*, EC, and dissolved oxygen; chlorophyll *a* in Mildred Island, for example, has been shown to vary ten-fold from the northern end to the southern end. The predicted success of "recirculation" of water through the reservoirs relies on reservoirs acting as a Continuously Stirred Tank Reactor, within which concentrations are uniform. If horizontal mixing is incomplete, then the effectiveness of recirculation may be limited. The panel therefore recommends that a multidimensional numerical

model of hydrodynamics and transport be implemented to study potential horizontal variability in water quality and key processes. A very important step in this effort could involve simulation of transport of passive, conservative tracers (e.g. numerical "dye") to visualize and quantify spatial differences in water residence time, vertical mixing rates, horizontal dispersion, etc.

CALSIM

The CALSIM model is an impressive tool that simultaneously accounts for numerous operational constraints in deciding how, when, where, and how much water can be moved from one location to another. This tool appears to incorporate variability in hydrology and, to some degree, climate, but it is unclear whether or how evaporation and precipitation are accounted for, whether for past and present scenarios or for future scenarios. How much could accounting for these processes, as well as sea level rise and long-term change in air temperature (see above) change the answers?

With respect to use of CALSIM for this particular study, the Panel understands that CALSIM is not currently equipped to simultaneously account for constraints on DOC, DO, T, and EC. We realize that making such changes to the code would be quite complex and time-consuming. On the other hand, we cannot currently evaluate interactions between different types of reservoir operation constraints. Such interactions are important because a sequence of constraints on water release could potentially result in long periods (>1 yr) without the possibility of release. For example, once a DO constraint is lifted, a temperature constraint could become applicable, followed by other constraints. We do not currently know how likely such scenarios are, and therefore recommend further work to simultaneously investigate sequential reservoir release constraints due to the full range of applicable water quality, flow, and environmental restrictions.

Finally, as a major step in estimating uncertainty, we encourage the CALSIM modelers to think creatively to find ways to estimate the size of uncertainty associated with CALSIM predictions of water yield. Without some estimate of how big the CALSIM error typically is, we cannot draw any conclusions on "how wrong we could be" or on the adequacy of the science employed in this feasibility study.

DSM2

The DSM2 model is a powerful tool that has been used extensively and shown to work well in calculating transport of water and conservative tracers. There are, however, several issues which could limit the reliability or usefulness of the DSM2 results in this study. First, DSM2 appears to have difficulty handling complete or near-drying of reservoirs. Shallow reservoir depths will be potentially critical periods for natural organic matter and mercury transformations; therefore, this problem needs to be addressed. Second, it is not clear whether evaporation and precipitation are accounted for. Third, there is disagreement over the appropriate seepage flow rates to use in the simulations. Fourth, there are questions as to the correctness of the particle tracking results; predicted particle trajectories should be compared (at least qualitatively) to any other relevant data available (e.g., USGS drogue and dye release studies). Finally, we would like to reiterate the importance of quantifying uncertainties associated with this model.

Panel Conclusions

The Review Panel has identified important short-comings of the current scientific studies supporting In-Delta Storage. Key uncertainties still exist and the generation of new understanding (information) is essential before the pros and cons of the project can be fully evaluated. Few decisions about implementation require complete scientific knowledge. However, some of the current uncertainties are severe enough that substantial risks exist if decisions proceed without further elucidation of these issues.

The review has identified substantial uncertainties regarding the water quality of the discharges from the project. The review has documented inadequate consideration of the processes controlling DOC concentrations and DO levels, both of which are important to the viability of the project. Implementing the project before these issues are more fully addressed poses great risk for the quality of water in the lower Delta and for the operators of the project who may fail to realize the expected benefits of the project because of water quality criteria. Several additional issues, such as the potential for mercury methylation, need to be addressed in order that the full implications of the project for the Delta can be assessed.

During the review process, the Panel has provided recommendations on research required to move towards an informed decision on in-delta storage implementation. To expedite development of crucial information for decision-makers, the Review Panel urges the use of the best available expertise in the various fields of science including state agency personnel, consultants, and both in- and out-of-state experts.